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UNIVERSITY OF PITTSBURGH, PITTSBURGH, PA.

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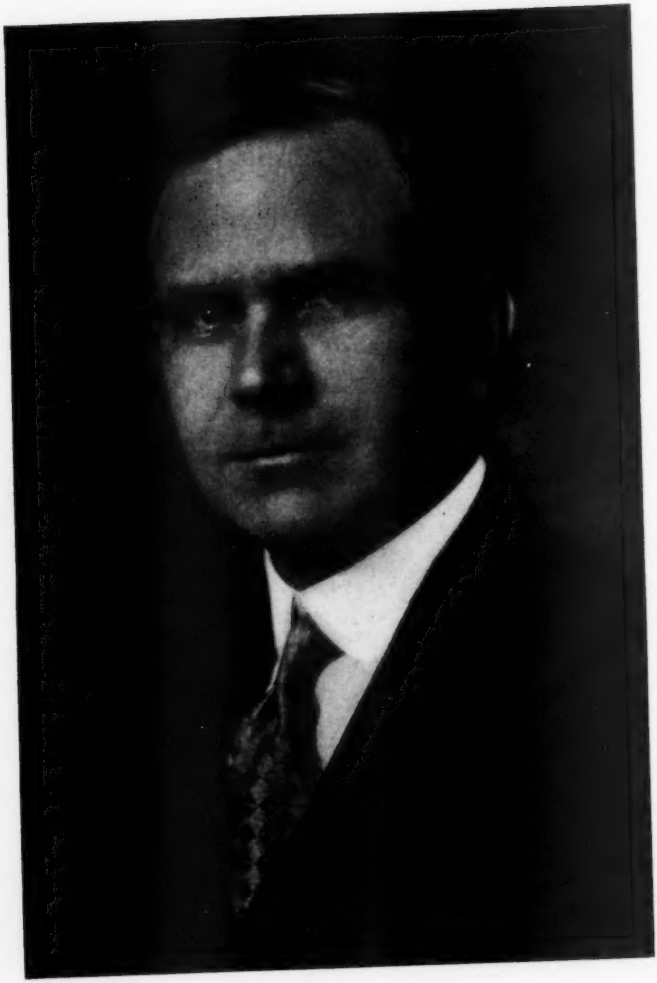


CLEMENT CLARENCE WILLIAMS

UNIV. OF MICH.

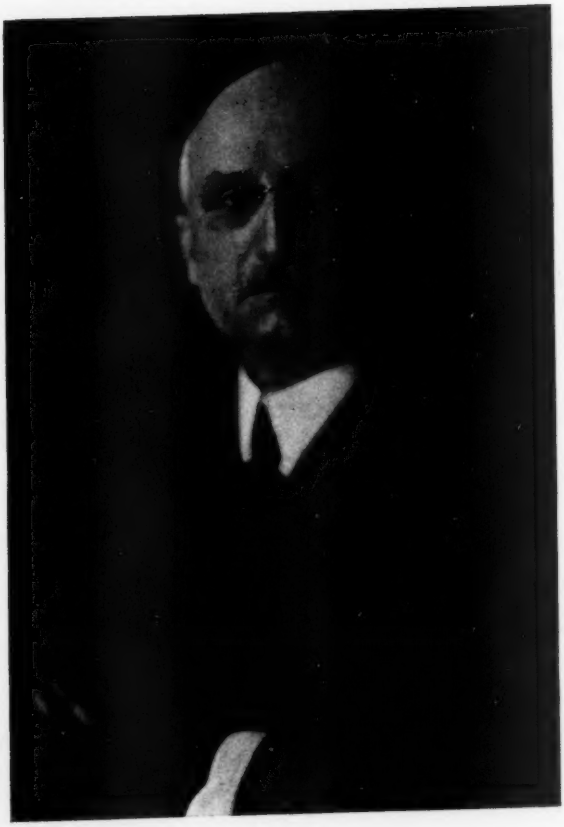
## CLEMENT CLARENCE WILLIAMS, PRESIDENT OF THE SOCIETY, 1934–35

President Williams was born at Bryant, Illinois, February 21, 1882. He received B.S. in C.E. at University of Illinois 1907 and C.E. at the University of Colorado in 1909. During the year 1905–6, and the summer, 1907, he worked in the engineering department of the D. L. & W. R. R.; in the summer 1908, he was topographic draftsman, Colorado Geological Survey; in the summer 1909, he was superintendent of construction on bridge erection at Denver with H. S. Crocker, Consulting Engineer; in the summers 1910–16, he was checker and designer in the engineering department of the C. M. & St. P. Ry. and in the summer 1917, in a similar capacity with the Illinois Central R. R. He spent the summer 1919 in Europe studying engineering and transportation problems.

The years 1908–14, at the University of Colorado as instructor, assistant professor, and acting professor of civil engineering; the years 1914–1922 at the University of Kansas as professor of railway engineering and as professor and head of the department of civil engineering. On leave 1918, he served as Supervising Engineer in the U. S. War Department on the construction of Explosives Plant C. at Nitro, West Va.; 1922–26, professor and head of the department of civil engineering, University of Illinois; 1926 to date, dean of the college of engineering, University of Iowa. Served at diverse times as a consultant to cities and as an expert in railway rate litigation for various state utility commissions; at present, member of the Governor's Public Works Advisory Committee and technical adviser to the Iowa State Planning Board.

Besides numerous articles and discussions in engineering periodicals, society proceedings, and bulletins, Dean Williams is the author of the following works: "Design of Railway Location," Wiley & Sons, "Design of Masonry Structures and Foundations," McGraw-Hill Book Company, "Building an Engineering Career," same, "Foundations" (Section of Civil Engineering Handbook), same, "Valuation of Public Utility Property," Edwards Brothers.

In addition to the scholastic societies Tau Beta Pi, Sigma Xi, and Sigma Tau, he is a member of the American Society of Civil Engineers (Past president, Central Illinois Section), the American Railway Engineering Association, the Iowa Engineering Society, a Fellow of A. A. A. S. and of the Royal Society of Arts (London). He is a registered Professional Engineer in Iowa and Structural Engineer in Illinois. He was a charter member of the Kansas-Nebraska section S. P. E. E., member of the Council 1922–25, vice-president 1928–29 and has served on various committees.



EDWARD ROSE MAURER

## EDWARD ROSE MAURER AWARDED THE SEVENTH LAMME MEDAL

EDWARD ROSE MAURER, Professor of Mechanics, University of Wisconsin, Madison, Wisconsin, awarded the seventh Lamme medal by the Society for the Promotion of Engineering Education at its forty-second annual meeting at Cornell University, Ithaca, N. Y., June 19–23, 1934.

THE LAMME MEDAL

Awarded by the Society each year to a chosen technical teacher for accomplishment in technical teaching or actual advancement of the art of technical training

Professor Maurer was born at Fountain City, Wisconsin, February 18, 1869. He entered the University of Wisconsin in 1886 and was graduated in 1890 with the degree B.C.E. After graduation he was first employed as assistant engineer with the Chicago and Northwestern Railway. In 1891–92 he was with the United States Geological Survey, leaving that position in September, 1892, to become an instructor in engineering at the University of Wisconsin. He was later made assistant professor and, in 1901, professor of mechanics, a position which he still occupies.

His teaching experience of over forty years is distinguished by devotion to the study and exposition of engineering mechanics and by inspiration and helpfulness to both students and associates. Through his guidance and genius in the art of organization, he has established an outstanding department both in excellence of teaching and in research.

He has been a member of the Society for the Promotion of Engineering Education since 1897; was a member of the Council, 1909–12; Vice-President of the Society, 1918–19; and director of the Summer School for Teachers of Engineering Mechanics held

at the University of Wisconsin in 1927. He is a member of the American Society for Testing Materials; The American Association for the Advancement of Science; and the Wisconsin Academy of Science, Arts, and Letters.

As an author, Professor Maurer has helped both the engineering student and the practicing engineer. His books are characterized by careful arrangement and clear presentation. They reflect his life-long study of the subject and his successful teaching. He has written: Technical Mechanics, 1903; Principles of Reinforced Concrete Construction, 1907; and Strength of Materials, 1925. He was also Associate Editor of the American Civil Engineers' Handbook, 1911, and is the author of a number of technical papers.

## TO THE SOUTHLAND

By C. C. WILLIAMS, *President of the Society*

Some of the members did not at once recognize the advantages of Atlanta as the place for the 1935 Convention. As for distance, Atlanta is no farther east than Columbus; for all colleges west of Cleveland, it is nearer than Boston; for New England, it is nearer than Chicago; for those west of the Indiana-Illinois line, it is nearer than Ithaca, where a record attendance gathered; for those south of the Ohio, is is, of course, next-door neighbor. The location of Atlanta at 1,100 feet above sea level gives it a mean summer temperature about 10 degrees lower than that at several of the midwest cities at which the convention has been satisfactorily held. Atlanta is a railway center and a focal point for highways, and hence, easy of access. The approach from almost any direction is through regions of rich historic import and of unsurpassed scenic beauty. In June, azalea and rhododendron will be in bloom, and peaches and melons will be prime. The projects of Muscle Shoals and the T. V. A., which may be seen along the way, will be of signal interest to all varieties of engineers. As for golf, remember that Bobby Jones is an alumnus of Georgia Tech., and no one knows what a few rounds on those magic links may do for your game.

The Convention itself will be—what you make it. Some of the committees are already at work and will have matured findings to report. The pre-convention conferences will be systematized so as to permit unified groups to discuss intimately their particular problems without overlapping and with everyone participating, but these conferences will not infringe upon the time or the zest of the main convention. Never before have more momentous questions confronted engineering education, and this convention will be the forum for their resolution. The place of graduate study and research in the engineering education picture, the sorts of engineering education required, employment and professional relations of young graduates, the development of a sound engineering and industrial economy as a part of engineering research, are pressures destined to shape engineering education. In this period of flux and transition, their resolution and adjustment partakes of the proportions of statecraft rather than of class-room techniques. We must look to common counsel for a solution, combining the aspiration of the younger with the experience of the maturer members. Such common counsel means year-round operation of S. P. E. E. with the harvest garnered at the Convention. The Committee will make the arrangements; you will make the Convention.

## ADDRESS OF WELCOME

A. R. MANN, *Provost, Cornell University*

As your President has well said, we are not much concerned with voicing welcome to this campus, as welcome is something that one feels and finds in the atmosphere and environment, if it be there; and we hope that you are finding it here.

It is my very simple, and I may say very pleasant responsibility, however, to bring you officially on behalf of the University a word of greeting, and to thank you for the pleasure which we at Cornell have in the fact of your presence on this campus. We have looked forward to this gathering with a great deal of anticipation, and we now find ourselves much stirred as we see it in all its reality and vitality.

As you well know, engineering education has been a major interest at Cornell from the foundation of the University. We therefore cherish any opportunity to associate ourselves with our sister institutions and leaders in the profession in any effort that will contribute to the advance of the profession of engineering education. An examination of your program is impressive of the scope and intensity with which you are proposing to reassess the methods and the materials as you find them in the several fields of engineering education.

My eye was naturally caught by the general subject for this session, or series of sessions, having to do with the effort to bring about a reconciliation between two things which at times are somewhat difficult to reconcile. Not knowing just how you might approach it, it brought to mind one aspect of the subject which apparently will not down in any gathering of persons interested in higher education, whether they be in the technical and professional fields or in the fields of the liberal arts and the sciences, namely, the accomplishment through the undergraduate curriculum on the part of the student of a certain mastery of a field of knowledge together with a measure of breadth which the business of living in society requires. The achievement of breadth and depth is a compelling objective in all fields of higher education. It is elusive, but it is a challenge to which educational administrators must always address themselves.

It happens that my own training and experience have been in technical fields primarily. In the fields with which I have been associated much help has been gained in facing this insistent prob-

lem by keeping constantly in mind that those who deal with the technical and professional fields of education are concerned, just as fully as those engaged with the liberal arts and the sciences, with the processes of education, with the higher education of youth; in the present case, with enabling students to acquire a higher education by means of engineering subjects. Education is the end; engineering subjects the means. In some of our institutions and in many of our organizations we are prone to confuse the ends with the means and often to substitute the means for the ends. We are concerned with the end of educating youth. We use varied means for accomplishing this purpose. By keeping this distinction always in mind and holding clear the responsibility for the higher education implicit in our work we have a stabilizer which will help accomplish the reconciliation between breadth of culture and technical specialization in the curriculum.

Another equally important guide lies in recognizing that our institutions cannot educate for life. Life is not fixed and it is not static. It is affected by a series of constantly changing scenes and situations and problems and experiences. Education must prepare one for effective adjustments to the changing demands upon his powers. This may be accomplished in part by the character of the curriculum and in part by sustained efforts to implant in the minds of our students the fact that all of life is learning in the technical and professional fields as well as in the general experiences of life, and that one's systematic education should be continuous and coterminus with life. Failure to implant this fact securely results in large numbers of young men and women going out from our institutions without motivation for continued study and learning, the absence of which makes very difficult their effective adjustment to these changing situations.

I notice from your program that it is to such questions as these, among many others, you will address yourselves. Our wish for you while you are here on the campus is that the light of insight will guide your discussions and that progress will mark your deliberations; and it must be so with the quality of your personnel. You are Cornell's very welcome guests, and, Mr. President, if there be any keys about the place, they are yours.

## MINUTES OF COUNCIL MEETINGS. CORNELL UNIVERSITY. JUNE 19, 21, 22, 23

Present: W. E. Wickenden, B. M. Brigman, W. O. Wiley, F. L. Bishop, L. E. Conrad, F. L. Eidmann, A. M. Dudley, B. G. Elliott, A. E. Norton, G. A. Stetson, E. R. Wilcox, H. B. Dirks, F. E. Johnson, Morland King, C. W. Park, A. P. Poorman, F. E. Ayer, J. B. Finnegan, B. R. Van Leer, C. H. Willis, C. Frank Allen, D. C. Jackson, F. E. Turneaure, A. N. Talbot, A. M. Greene, C. F. Scott, A. A. Potter, O. M. Leland, R. L. Sackett, D. S. Kimball, R. I. Rees, R. A. Seaton, and Messrs. Daggett, Hammond and Wilson by invitation.

The reports of the Secretary and of the Treasurer were read and ordered printed.

The Executive Committee recommended the following which Council adopted:

"In view of the unsettled conditions which have existed in educational institutions during the last few years that all members who are in arrears on July 1, 1934, shall be placed in good standing upon the payment of arrears of one year and dues for 1934–35; also that

"For the next current year, beginning July 1, 1934, the dues for individual members be discounted in the amount of 10 per cent when such dues are paid prior to January 15, 1935, and that also all dues collectable after January 15, 1935, shall be for the full amount."

R. I. Rees, Chairman, reported for the Committee on Relations with Engineering Societies.

Council approved the Engineers' Council for Professional Development as the accrediting agency for engineering colleges.

Council accepted the final report of the Director of Summer Schools, H. P. Hammond, and thanked him for his distinguished service and for the highly significant value of that service to engineering education.

Council accepted the final report of the Chairman of the Board of Investigation and Coördination and gave the chairman, Charles F. Scott, a rising vote of thanks for his great part in the entire work of the Board.

"The Board of Investigation and Coördination, created by your letter ballot approval of the report of the Development Committee on August 8, 1922, presents this as its final report to the

Council and asks that it be officially terminated. The Board organized on September 29, 1922.

"The Board has not attempted to solve problems and to supply answers but rather to determine the basic facts and to formulate the principles which individuals and faculties may use in meeting their varied situations. The coöperation accorded by members of the Society and by others is greatly appreciated.

"The Board now recommends:

"That the Board be officially terminated.

"That the affairs of the Board be taken over by the officers of the Society including the custody and the disposition of existing pamphlets and reports, and the distribution of Vol. II.

"That the balance in the summer school account be held as a special fund available by action of the Council for related activities in the future."

FINANCIAL STATEMENT OF INCOME AND EXPENSES OF THE INVESTIGATION OF ENGINEERING SCHOOLS, DECEMBER 17, 1923–MAY 15, 1934

| | | | |
|---|---|---|---|
| RECEIPTS: | | | |
| Carnegie Corporation | | $108,000.00 | |
| Subscriptions to special fund for investigation | | 48,400.00 | |
| Gifts for publications of Society: | | | |
| Carnegie Corporation | $10,000 | | |
| Carnegie Foundation for the Advancement of Teaching | 6,000 | 16,000.00 | |
| Sales of Pub., lantern slides, etc. | | 882.90 | |
| Interest on daily bank balances | | 2,408.04 | $175,690.94 |
| DISBURSEMENTS: | | | |
| Salaries of Director and Staff | | $110,232.01 | |
| Rent, etc. | | 8,845.16 | |
| Expenses of Staff | | 8,230.12 | |
| Expenses of Board | | 7,732.96 | |
| Committee Expenses | | 672.82 | |
| Director's investigations in Europe | | 2,220.20 | |
| Publications | | 7,931.61 | |
| Office supplies, equipment, etc. | | 6,557.13 | |
| Institutional Division—personnel probs. | | 1,000.00 | |
| Publications—special fund | | 16,722.24 | $170,144.25 |
| BALANCE ON HAND, MAY 15, 1934 | | | $ 5,546.69 |
| ANALYSIS OF BALANCE ON HAND: | | | |
| Mellon National Bank, Pittsburgh, Pa. | | | $ 37.58 |
| Forbes National Bank, Pittsburgh, Pa. | | | 5,509.11 |
| | | | $ 5,546.69 |

FINANCIAL STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS OF THE INVESTIGATION OF TECHNICAL INSTITUTES, FEB. 27, 1928–MAY 15, 1934

| | | |
|---|---|---|
| RECEIPTS: | | |
| Pratt Family | $ 5,000.00 | |
| Carnegie Corporation | 24,000.00 | |
| Ohio Mechanics Institute | 1,000.00 | |
| Interest on daily bank balances | 608.27 | $30,608.27 |
| DISBURSEMENTS: | | |
| Salaries of staff | $20,826.67 | |
| Stenographic and clerical assistance | 2,453.72 | |
| Technical Institute report | 2,238.08 | |
| Office rent, etc. | 1,428.28 | |
| Office supplies and equipment | 722.38 | |
| Traveling expenses and entertainment | 1,852.37 | |
| Committee expenses | 126.36 | |
| W. E. Wickenden—Study European Schools | 873.11 | $30,520.97 |
| CASH BALANCE, MAY 15, 1934 | | $ 87.30 |
| ANALYSIS OF CASH BALANCE: | | |
| Forbes National Bank, Pittsburgh, Pa. | | $ 28.70 |
| Petty cash fund—R. H. Spahr | | $ 58.60 |
| | | $ 87.30 |

STATEMENT OF RECEIPTS AND DISBURSEMENTS, SUMMER SESSIONS, JANUARY 1, 1927 TO DECEMBER 20, 1933

| | | |
|---|---|---|
| RECEIPTS: | | |
| Tuition from Students | | $ 7,040.00 |
| Contributions: | | |
| Carnegie Corporation | $35,000.00 | |
| Chemical Foundation | 5,000.00 | |
| Engineering Foundation | 3,000.00 | |
| American Society of Chemical Engineers | 2,500.00 | |
| American Society of Mechanical Engineers | 2,500.00 | |
| Carnegie Institute of Technology | 2,500.00 | |
| Highway Education Board | 2,500.00 | |
| Massachusetts Institute of Technology | 2,500.00 | |
| Purdue University | 2,500.00 | |
| University of Michigan | 2,500.00 | |
| University of Minnesota | 2,500.00 | |
| Yale University | 2,500.00 | |
| Western Electric Co. | 1,500.00 | |
| Westinghouse Electric & Mfg. Co | 1,500.00 | |
| Portland Cement Co. | 1,000.00 | |
| C. W. Gould | 500.00 | $70,000.00 |
| Interest on Bank Balances | | 1,241.22 |
| Total Receipts | | $78,281.22 |

| | | |
|---|---|---|
| DISBURSEMENTS: | | |
| Salaries of Director, Staff and Clerical Assistants (Including expenses of staff) | $50,258.88 | |
| Printing and Publications | 9,675.90 | |
| Office Expense | 1,962.77 | |
| Traveling Expenses, etc.—Director | 2,822.38 | |
| Expenses prior to 1929 Summer Schools (Undistributed) | 9,882.03 | $74,601.96 |
| BALANCE ON HAND—DECEMBER 20, 1933 | | $ 3,679.26 |
| ANALYSIS OF BALANCE ON HAND: | | |
| Checking Account—Forbes National Bank | $ 1,336.47 | |
| Certificate of Deposit—Forbes National Bank | 2,000.00 | |
| Petty Cash Fund—H. P. Hammond, Director | 342.79 | $ 3,679.26 |

The Chairman, R. A. Seaton, presented the report of the Committee on Summer Schools for Engineering Teachers and asked that the committee be re-appointed for 1934–35 to continue the study of the problem and to keep the project alive and to report back its findings to the Council in 1935. The committee was given free range to study the problem and to submit recommendations but it is not to act without authority in any essential capacity involving the work of the Society. It is to be an inoperative committee. However, if summer schools can be organized and maintained then a committee on summer schools should be charged with supervising authority.

The plan of conferences at the Cornell meeting was approved for 1935.

F. L. Bishop was elected for three years as a representative of this Society on the American Council on Education—H. S. Jacoby, L. W. Wallace.

The secretary was re-appointed the representative of this Society on the American Engineering Council.

The following petitions were approved:

1. "The teachers of civil engineering of the Society for the Promotion of Engineering Education hereby petition the Council to authorize a "Division of Civil Engineering" to be composed of such members of the Society as may choose to join it. There are more than 400 members of the Society who would be eligible to membership in such a division.

"The active governing group of the division shall be an executive committee of six members, two of whom shall be elected each year for a term of three years; except that in the case of the first regular election, two members shall be elected for a term of one year, and two for a term of two years. The two members

of the executive committee elected for one year terms at the first annual election shall be members of the present Committee on Civil Engineering.

"The officers of the division shall be a chairman and a secretary who shall be elected annually at the time of the annual election and who shall have been members of the executive board or members of the Committee on Civil Engineering for at least one year prior to their election as officers. They must be members of the executive committee. No person who has been on the Committee on Civil Engineering for two years may serve on the committee within two years.

"The annual election of the division shall take place during the regular meeting of the Society and at such time and place as may be designated by the executive committee.

"The activities of the Division shall be prescribed by the executive committee.

(signed) L. E. CONRAD, *Chairman, Committee on Civil Eng.*

"Executive Committee:

For one year: T. R. Agg, Iowa State College; G. M. Fair, Harvard University.

For two years: Frank Kerekes, Iowa State College; F. L. Plummer, Case School of Applied Science.

For three years: L. E. Grinter, A. & M. College of Texas; K. C. Reynolds, Mass. Inst. of Tech."

2. "The undersigned, unofficially representing the Mathematics Conference of the S. P. E. E. annual convention held at Cornell University, June 19–20, 1934, unanimously recommend the following action:

"Whereas the widespread and increasing interest in advanced courses in mathematics for engineering students in America has hitherto expressed itself in a diversity of courses and topics taken up for special study—and

"Whereas no survey of practice in this field has yet been undertaken;

"Therefore, we recommend with a view to future improvements —and to serve as a basis for future intelligent discussion—that *a fact-finding survey* be undertaken by a national committee appointed for this purpose, to determine what is being done and is now being recommended in collegiate and industrial organizations giving such advanced mathematical work.

(signed) A. A. BENNETT, T. C. FRY, V. S. LAWRENCE, JR.,
H. W. MARCH, J. H. WEAVER,
RICHARD S. BURINGTON, *Chairman of Conference.*"

A letter from the University of Utah relative to the abolishment, under the new code, of the discount to educational institutions was referred to the Committee on Relations with Industrial and Trade Associations.

It was the sense of the Council that, if possible, a suitable certificate of membership be made available and the matter was referred to the Executive Committee with power to act.

Invitations to meet in 1935 were received from the University of Minnesota, the University of Wisconsin, the Kansas State College, Georgia School of Technology, New York City, Massachusetts Institute of Technology, and the Pennsylvania State College. Georgia School of Technology was selected for the 1935 meeting.

Massachusetts Institute of Technology and the Pennsylvania State College extended invitations for the Society to meet there in 1936.

The report of the Committee on Titles of College Degrees in Engineering was presented by the chairman, O. M. Leland. Council voted to present the report to the Society this year but that no action would be taken until it is reported again to the Council in 1935.

Council accepted the report on sections and branches presented by C. G. Thatcher, Chairman.

The Division on Drawing recommended the adoption of the "Proposed American Standards Drawings and Drafting Room Practice, Nos. Z14 and Z14f." Approved by Council.

The question of the publication of papers presented at the 21 conferences held in connection with this annual meeting was referred to the Publication Committee with the suggestion that, early in the fall, about fifty pages of abstracts of the conferences be printed in the JOURNAL OF ENGINEERING EDUCATION.

The chairman, R. A. White, of the Committee on Junior Colleges, recommended that the Council consider a survey of junior colleges similar to the one on technical institutes. Council approved the appointment of a committee to consider the matter of institutional membership in the Society with particular reference to junior colleges.

Council adopted the following budget for 1934–35:

| RECEIPTS: | | |
|---|---|---|
| Current dues | $9,915.00 | |
| Back dues | 500.00 | |
| Advertising | 1,600.00 | |
| Interest on saving account | 180.00 | |
| Sale of publications | 400.00 | |
| For conference from summer school funds for 1934... | 500.00 | $13,095.00 |

DISBURSEMENTS:

| | | | |
|---|---|---|---|
| 1934 meeting | | $ 460.00 | |
| Conference for 1934 | | 500.00 | |
| JOURNAL and Proceedings | | 6,000.00 | |
| Honorarium, Secretary | | 1,200.00 | |
| Clerical assistance | | 3,300.00 | |
| Sundry printing | | 100.00 | |
| Postage, telephone and telegraph | | 300.00 | |
| Supplies | | 100.00 | |
| Travel, Secretary's office | | 500.00 | |
| Dues: Amer. Eng. Council | $250.00 | | |
| Amer. Coun. on Ed. | 100.00 | 350.00 | |
| Committee expenses | | 150.00 | $13,060.00 |
| Estimated surplus | | | $ 35.00 |

The following applicants were elected to membership:

BRIGGS, GARLAND, Director of Education, International Business Machine Co., 108 Stockton St., Princeton, N. J. C. H. Willis, F. L. Eidmann.

BURINGTON, RICHARD S., Assistant Professor of Mathematics, Case School of Applied Science, Cleveland, O. W. E. Wickenden, T. M. Focke.

CHAPIN, LLOYD W., Associate Professor of English, Georgia School of Technology, Atlanta, Ga. A. D. Holland, N. C. Ebaugh.

COMPTON, HORACE B., Assistant Professor of Rational and Technical Mechanics, Renssalear Polytechnic Institute, Troy, N. Y. L. W. Clark, E. R. Cary.

CRABTREE, FREDERICK H., Instructor in Civil Engineering, Tufts College, Tufts College, Mass. F. N. Weaver, Robinson Abbott.

HEROD, NEWTON S., Professor of Physics, Georgia School of Technology, Atlanta, Ga. A. D. Holland, N. C. Ebaugh.

KANTNER, ROBERT C., Assistant Professor of Chemical Engineering, Bucknell University, Lewisburg, Pa. S. C. Ogburn, F. E. Burpee.

KRYNINE, D. P., Research Associate in Soil Mechanics, Yale University, New Haven, Conn. C. F. Scott, R. S. Kirby.

MALCOLM, W. L., Professor of Mining Engineering, Queen's University, Kingston, Ont. C. L. Walker, E. N. Burrows.

MILLS, G. H., Case School of Applied Science, Cleveland, O. Reinstated.

MIRABEL, I. EUGENE, Assistant Professor of Structural Design, Massachusetts Institute of Technology, Cambridge, Mass. C. B. Breed, J. B. Babcock.

MOENCH, HERMAN A., Instructor in Electrical Engineering, Rose Polytechnic Institute, Terre Haute, Ind. C. C. Knipmeyer, D. B. Prentice.

O'DONNELL, RAYMOND, Professor of Hydraulic and Sanitary Engineering, Pennsylvania State College, State College, Pa. E. D. Walker, H. B. Shattuck.

OWENS, THURSTON D., Assistant Professor of Electrical Engineering, Case School of Applied Science, Cleveland, O. R. C. Putnam, T. M. Focke.

PERKINS, HAROLD C., Assistant Professor of Mechanics, Cornell University, Ithaca, N. Y. D. S. Kimball, J. E. Perry.

PHELPS, R. THAYER, Instructor in Chemistry, Colorado School of Mines, Golden, Colo. R. A. Baxter, I. A. Palmer.

REYNOLDS, KENNETH C., Assistant Professor of Hydraulics, Massachusetts Institute of Technology, Cambridge, Mass. W. H. Timbie, F. L. Plummer.

SCHODER, ERNEST W., Professor of Experimental Hydraulics, Cornell University, Ithaca, N. Y. C. L. Walker, P. H. Underwood.
TARPLEY, HAROLD I., Associate Professor of Electrical Engineering, Pennsylvania State College, State College, Pa. L. A. Doggett, C. E. Govier.
THOMPSON, MILTON J., Assistant Professor of Aeronautical Engineering, University of Michigan, Ann Arbor, Mich. H. L. Mason, E. L. Ericksen.
WILBUR, JOHN B., Assistant Professor of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Mass. J. W. Howard, C. B. Breed.
LOUISIANA STATE UNIVERSITY, Baton Rouge, La. L. J. Lassalle, Dean.

Council gave a rising vote of thanks to Dean Kimball for the many courtesies extended by him to us at this meeting.

Respectfully submitted,

F. L. BISHOP, *Secretary.*

## MINUTES OF THE FORTY-SECOND ANNUAL MEETING, SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, CORNELL UNIVERSITY, JUNE 19–23, 1934

The forty-second annual meeting of the Society for the Promotion of Engineering Education was held at Cornell University, Ithaca, N. Y., June 19–23, 1934. There were 1,109 members and guests registered. The meeting was divided into two parts—Tuesday, Wednesday, and Thursday morning were devoted to conferences on twenty-one different subjects; Thursday afternoon, Friday, and Saturday morning were given over to the annual meeting, the theme of which was "Reconciling the Professional and General Aspects of Engineering Education."

The aim of each conference was to bring together a group of men who are doing pioneer work for a pooling of experience and for mutual guidance and stimulation. Over 900 were registered prior to the opening of the general sessions which is proof of the interest in the conferences. Each of the twenty-one conferences was sponsored by a special committee which arranged the program and secured the speakers. The following conferences were held: Chemical Engineering Unit Operations Teaching; Civil Engineering; Coöperative Engineering Education; Deans and Administrative Officers; Drawing; Electrical Engineering; Electronics and Electrical Communications; Engineering Economy; Engineering Research; English; Fluid Mechanics; Heat Transfer; Industrial Engineering; Junior Colleges; Laboratory Procedure in Teaching Machine Production; Machine Design; Mathematics; Mechanical Engineering; Pre-College Guidance and the Orientation of Freshmen; Technical Institutes; and Laboratory Use of Models in Structures and Hydraulics.

There were several interesting exhibits held in connection with the conferences: Models used in teaching structures, hydraulics and sanitary engineering; Instruments and old drawings; Historical textbooks; Drawings; and Electronics and Electrical communications. These exhibits were very instructive and made valuable additions to the meetings.

The social side of the program was well taken care of by our host, Cornell University. On Tuesday afternoon there was a tea in the Womans Lounge in Willard Straight; at seven that evening a dinner was given to the Council and one to the wives of Council

members; walking trips were arranged through Cascadilla and Fall Creek Gorges and auto trips through the State parks and nearby points of interest; a reception and tea on Wednesday afternoon was followed by a bridge that evening; a musicale and social get-together on Thursday evening and a garden party on Friday concluded the social program.

### THURSDAY, JUNE 21, 1934

The opening session of the forty-second annual meeting was called to order at two o'clock by the President of the Society, W. E. Wickenden, President of Case School of Applied Science. Albert Russell Mann, Provost, welcomed the Society to Cornell.

Vice-President B. M. Brigman took the chair while President Wickenden delivered his Presidential Address, "Discipline and Discipleship." Harvey N. Davis, Stevens Institute of Technology, presented his topic "Are Engineering Schools Primarily Technical Schools?" "Readjustment of Purpose and Program in Engineering Education" was presented by R. E. Doherty, Yale University. Gordon M. Fair, Harvard University, spoke on "The Liberal Pursuit of Engineering Studies." The reports of the Secretary, F. L. Bishop, and of the Treasurer, W. O. Wiley, were read and ordered printed.

At eight o'clock there was an informal musicale furnished by members of the Cornell Engineering Faculty.

### FRIDAY, JUNE 22, 1934

The second session was called to order by President Wickenden at nine thirty. This session was devoted to a symposium on "Marketing the Services of the Engineering Graduate." The discussion was led by W. A. Shoudy, Columbia University, followed by Samuel S. Board, Yale Graduates Placement Bureau; A. D. Moore, University of Michigan; S. B. Earle, Clemson College; O. W. Eshbach, American Tel. & Tel. Co.; E. J. Freund, University of Detroit; C. C. Williams, University of Iowa; M. G. Malti, Cornell University; J. E. McDaniel, Georgia School of Technology; E. D. Walker, Pennsylvania State College; A. B. Domonoske, Stanford University; R. W. Sorensen, California Institute of Technology. L. A. Doggett presented the report of a committee from The Pennsylvania State College on "Are There Too Many Engineers?"

The third session began at two o'clock with Vice-President Brigman in the chair. This session was devoted to reports. Charles F. Scott, Chairman, presented the final report of the Board of Investigation and Coördination. The Society endorsed the action of Council in accepting the recommendations that the Board be

terminated; that the affairs of the Board be taken over by the officers of the Society including the custody and disposition of Vol. II; and that the balance in the Summer School account be held as a special fund available by action of Counеil for related activities in the future. The Society also gave Dr. Scott a rising vote of appreciation and thanks for his part in the work of the Board.

Chairman R. E. Doherty, Yale University, gave a report of progress on the work of the Committee on Length of Curriculum. The society voted to recommend that the present committee be continued as a Committee on Objectives and Lengths of Curricula.

The report of the Committee on Engineering Degrees was presented by the Chairman, O. M. Leland, University of Minnesota. No action was taken except to instruct the Committee to report again in 1935, and recommend that a copy of this report be sent to each section and branch for consideration.

Chairman H. P. Hammond, Brooklyn Polytechnic Institute, reported for the Committee on Graduate Studies, as did Chairman R. A. Seaton, Kansas State College, for the Committee on Summer Schools.

A paper, "Honors Group," was read by R. H. Frazier, Massachusetts Institute of Technology, and one on "An Industrial Engineering Curriculum" was presented by Paul T. Norton, Jr., Virginia Polytechnic Institute.

Sada A. Harbarger, Ohio State University, reported for the conference on English; H. L. Mason, Columbia University, for the conference on Fluid Mechanics; R. A. White, Grand Rapids Junior College, for the conference on Junior Colleges; R. L. Sweigert, Georgia School of Technology, for the conference on Laboratory Procedure in Teaching Machine Production; F. L. Eidmann, Columbia University, for the conference on Machine Design; F. C. Dana, Iowa State College, for the conference on Pre-College Guidance and Freshman Orientation; W. B. Russell, Franklin Union, for the conference on Technical Institutes; and J. E. McDaniel, Georgia School of Technology, for the conference on Coöperative Engineering Education.

The annual dinner was held in the beautifully decorated Memorial Hall of Willard Straight with President Wickenden presiding. O. W. Eshbach, American Tel. & Tel. Co., Chairman of the Committee on Lamme Award, presented the report of that committee and concluded the report with the recommendation that the seventh Lamme medal be awarded to Edward Rose Maurer, Professor of Mechanics at the University of Wisconsin. President Wickenden presented the gold medal to Professor Maurer who accepted it with appreciation of the honor conferred upon him.

F. P. Keppel, President of the Carnegie Corporation, spoke

informally on engineering education. The Nominating Committee made the following report and upon motion the Secretary cast the unanimous ballot of the Society for the officers and members of the Council:

For President: C. C. Williams, State University of Iowa.
For Vice-Presidents: H. P. Hammond, Brooklyn Polytechnic Institute; G. C. Shaad, University of Kansas.
For Secretary: F. L. Bishop, University of Pittsburgh.
For Treasurer: W. O. Wiley, John Wiley & Sons, Inc.
For elective members of Council for three years: G. P. Boomsliter, West Virginia University; Geo. W. Case, University of New Hampshire; C. E. Davies, A. S. M.E., New York City; Harvey N. Davis, Stevens Institute of Technology; C. L. Eckel, University of Colorado; P. T. Norton, Virginia Polytechnic Institute; W. T. Ryan, University of Minnesota.

SATURDAY, JUNE 23, 1934

The fourth session convened at nine thirty with President Wickenden in the chair. The topic of this session was "Professional Recognition and Educational Standards." C. Frank Allen, Massachusetts Institute of Technology, read his paper on "Educational Background of Certain Distinguished Engineers." Discussion. C. F. Hirshfeld, Chairman, discussed the Engineers' Council for Professional Development, followed by the Secretary, C. E. Davies, A. A. Potter, Purdue University, C. L. Dawes, Harvard University, W. C. John, Office of Education, L. A. Doggett, Pennsylvania State College, A. H. Lovell, University of Michigan, P. H. Daggett, Rutgers University, C. F. Scott, Yale University, and R. I. Rees, American Tel. & Tel. Co.

H. S. Rogers, Brooklyn Polytechnic Institute, presented the report of the Committee on Instructional Standards; discussed by L. O. Stewart, Iowa State College, R. A. Seaton, Kansas State College, and D. C. Jackson, Massachusetts Institute of Technology.

H. C. Sadler, University of Michigan, made a motion that the Society for the Promotion of Engineering Education hereby wishes to record its deep sense of appreciation to Cornell University and to members of its staff for the wonderful manner in which they have taken care of all the arrangements, both physical and spiritual, for these meetings. This was unanimously adopted.

The meeting adjourned at 11:30 A.M. to meet at the Georgia School of Technology in June, 1935.

## REPORT OF THE SECRETARY, 1933–34

F. L. BISHOP

The Society, as a whole, is in a healthy condition. The Treasurer's report will show a small surplus for the current year. The membership shows an increase of 34. Papers presented at sectional meetings have been of exceptional quality and the attendance has been most gratifying. The organization of active sections and branches has been one of the features of the Society's work, especially during the last three years. During the past year approximately 50 meetings of sections and branches have been held. In the case of branches, the attendance was confined largely to members of the faculty of a given institution. In the case of sections, representatives from several colleges attended, in some cases the attendance being as large as the annual meeting was only a few years ago. The organization of sections is progressing to such an extent that we will shortly be able to say that there is a section serving every member of the Society. Professor C. G. Thatcher, Chairman of the Committee on Sections and Branches, will make a detailed report on this matter.

Professor H. P. Hammond, Director of Summer Schools, will give you his final report on the summer schools for engineering teachers. These were started in 1927 at Cornell University and at the University of Wisconsin. They have been continued each year under his able direction but, due to lack of funds, there will be no summer school for 1934. However as a substitute, a number of clinical conferences are being held at the annual meeting. President Wickenden conceived the idea of expanding the conferences and assigning to each a specific topic which might be well treated in the time available. Consequently, the time devoted to conferences and the number have been greatly expanded. The Board of Investigation and Coördination, through its Committee on Summer Schools, made an appropriation of $500, from unexpended funds belonging to the summer schools, to cover a portion of the expenses of these conferences. The basic idea of these conferences is to combine a modified summer school with the annual meeting. There are two broad matters of policy concerning these which should be considered by the Council:

1. Securing funds.
2. Adequate provision for publication of papers presented.

The number of conferences held in connection with the annual

meeting has been expanded from 11 to 21 and the time devoted to them from a day and a half to two days and a half.

The Council, last year, on the recommendation of the Executive Committee, adopted the following resolution:

"That for the next current year, beginning July 1, 1933, the dues for individual members be discounted in the amount of 20 per cent when such dues are paid prior to January 15, 1934, and that also all dues collectable after January 15, 1934, shall be for the full amount."

This proved to be a wise move resulting in prompt payment of dues and the retention of many names on the rolls of the Society. 78.8 per cent of the members paid. The Council should consider the policy to be followed next year. 280 individual and 9 institutional members paid back dues, 33 have paid 1934–35 dues and 21 have paid portions of them. We received 56 resignations this year compared with 127 last year. We lost 14 by death—L. M. Defoe, E. C. Keenan, W. L. Robb, W. J. Dana, F. J. Pollay, F. A. Nagler, W. E. Dowd, A. S. Jones, R. E. Puerner, A. B. Morton, W. H. Wheeler, R. W. Thoroughgood, Everett Morss, J. A. Yates. The total membership is 2,298 individuals, 121 institutions, grand total of 2,419.

The Executive Committee will recommend to the Council that:

"In view of the unsettled conditions which have existed in educational institutions during the last few years, the Executive Committee recommends to the Council that all members who are in arrears on July 1, 1934, shall be placed in good standing upon the payment of arrears of one year and dues for 1934–35."

Also that

"For the next current year, beginning July 1, 1934, the dues for individual members be discounted in the amount of 10 per cent when such dues are paid prior to January 15, 1935, and that also all dues collectable after January 15, 1935, shall be for the full amount."

The facts show that the Society is stimulating a large number of individuals to take an active part in the promotion of engineering education.

A meeting of Deans and Administrative Officers was held last summer under the direction of the Board of Investigation and Coordination. A follow-up conference is planned for this meeting—the chief topic of discussion being "Occupational Demands." This takes the place on the program of the Institutional Division.

The Council at its meeting last June approved the charter of the Engineers Council for Professional Development. This organization has been active and is presenting to the Council at this time a proposed method for the accrediting of engineering colleges.

Professor Chas. F. Scott, Chairman of the Board of Investigation and Coördination, will present a final report closing the work of that organization.

The increase in the number of junior colleges giving work in engineering and their interest in this Society is strikingly illustrated by the excellent program of the conference on that subject. A significant fact is that a portion of the time of this conference will be devoted to an open discussion of "formulation of future activities of the Junior College Division." Junior Colleges are, I believe, destined to have a direct effect on the work of the four-year engineering college and is, therefore, an important matter for the consideration of this body. I suggest that some form of institutional membership be provided for junior colleges.

# REPORT OF THE TREASURER, 1933–34

W. O. WILEY

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

STATEMENT OF CASH ACCOUNT

JUNE 13, 1934

| | | |
|---|---|---|
| BALANCE ON HAND—JUNE 15, 1933 | | $ 1,504.00 |
| RECEIPTS: | | |
| Current Dues | $8,575.70 | |
| Back Dues | 1,361.47 | |
| Dues in Advance | 158.50 | |
| Sales of Publications | 1,374.69 | |
| Advertising | 1,111.60 | |
| Miscellaneous Income | 2.85 | |
| Interest on Daily Bank Balances | 1.70 | |
| Refund—Lamme Award Fund | 100.00 | $12,686.51 |
| Total | | $14,190.51 |
| DISBURSEMENTS: | | |
| Cost of Publications | $4,269.20 | |
| Cost of Proceedings | 382.71 | |
| Honorarium for Secretary | 1,200.00 | |
| Salaries—Secretary's Office | 3,300.00 | |
| Traveling Expenses—Secretary's Office | 222.16 | |
| Committee Expenses | 87.57 | |
| Printing, Postage, Office Supplies, etc. | 633.07 | |
| Expenses—1933 Meeting | 428.31 | |
| Expenses—1934 Meeting | 164.54 | |
| Dues—American Council on Education | 100.00 | |
| Dues—American Engineering Council | 250.00 | $11,037.56 |
| BALANCE ON HAND—JUNE 13, 1934 | | $ 3,152.95 |

*Note*—In addition to the above balance, there is on deposit at the Forbes National Bank, Pittsburgh, Pa., in Savings Account No. 3809 the amount of $6,000.00 with interest of $629.23 to June 1, 1934.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

INCOME AND EXPENSE STATEMENT

*For the Year Ending June 13, 1934*

EXPENSE

| | |
|---|---|
| Cost of JOURNAL | $ 4,668.25 |
| Cost of Proceedings | 382.71 |

| | |
|---|---|
| To Expenses—1933 Meeting | 485.65 |
| Honorarium for Secretary | 1,200.00 |
| Salaries—Secretary's Office | 3,300.00 |
| Printing, Postage, Office Supplies, etc. | 633.07 |
| Traveling Expenses—Secretary's Office | 222.16 |
| Committee Expenses | 87.57 |
| Dues—American Council on Education | 100.00 |
| Dues—American Engineering Council | 250.00 |
| | $11,329.41 |
| Surplus for the Year | 1,538.28 |
| | $12,867.69 |

INCOME

| | |
|---|---|
| Current Dues | $ 8,985.50 |
| Back Dues | 1,121.47 |
| Sales of Publications | 1,374.69 |
| Advertising | 1,269.10 |
| Miscellaneous Income | 2.85 |
| Interest on Daily Balances | 114.08 |
| | $12,867.69 |

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

BALANCE SHEET

JUNE 13, 1934

ASSETS

| | | |
|---|---|---|
| Cash: | | |
| Current Fund | $3,152.95 | |
| Petty Cash Fund | 300.00 | |
| Life Membership Fund | 746.65 | |
| Benj. G. Lamme Fund | 159.96 | $ 4,359.56 |
| Savings Account: | | |
| Forbes National Bank—No. 3809 | | 6,629.23 |
| Securities: | | |
| Benj. G. Lamme Fund | | 5,000.00 |
| Prepaid Expenses—1934 Meeting | | 164.54 |
| Inventory | | 1.00 |
| Accounts Receivable: | | |
| Current Dues | $ 240.00 | |
| Advertising | 398.32 | |
| Lamme Medal Fund | 900.00 | $ 1,538.32 |
| Furniture and Office Equipment (Estimated) | | 100.00 |
| | | $17,792.65 |

LIABILITIES

| | | |
|---|---|---|
| Life Membership Fund | | $ 746.65 |
| Benj. G. Lamme Fund | | 5,159.96 |
| Prepaid Membership Dues | | 158.50 |
| Accounts Payable | | 849.05 |
| Surplus Accounts: | | |
| Balance at June 15, 1933 | $9,340.21 | |
| Surplus for this Year | 1,538.28 | $10,878.49 |
| | | $17,792.65 |

# READJUSTMENT OF POLICY AND PROGRAM IN ENGINEERING EDUCATION

By ROBERT E. DOHERTY,

Dean, School of Engineering, Yale University

## I. Educational Policy

Education, like other growing human institutions, requires timely readjustments. If readjustment is postponed too long the result is just as bad as if it were made prematurely. In the one case education tends to become inadequate and even sterile; in the other, unrelated to vital social processes. Thus our problem is to maintain education in an optimum position in the moving procession of civilization such that it will neither find itself overtaken by the rear guard nor so far ahead that it is out of intimate touch and perhaps even off the track. That position should indeed be always one of leadership; but in order for it to be this, education must not remain too long in a settled state.

Like mass in Newton's First Law, education tends naturally to persist in its existing state. Certain phases of engineering education have unquestionably remained too long in such a state. The expansion of the field of engineering has placed a growing pressure upon the colleges and they have naturally tended to meet this merely by extending and multiplying curricula. This process of mere expansion, however, has not solved all phases of the problem; especially it has not solved the growing demand for intellectual leadership. I feel that engineering education, in common with all other, is lagging, not leading, the procession in this respect.

It is auspicious, however, that one finds this fact to be rather generally realized. This realization is indicated by numerous critical reviews of educational policy and methods. Over a period of years this Society has rendered a great service in encouraging such thought and discussion, and especially in conducting the comprehensive investigation during 1923–29. It seems to me that the Board's recommendations are sound, as far as they go; and also that it is quite possible that a more active and general recognition of them might have placed engineering education in a more appropriate position than it now occupies. However, the membership of the Society is at last astir with a searching interest, which is undoubtedly leading us to fresh starts along certain lines.

I have had occasion during the past decade to study the broad

problem of engineering education and now wish to present my results. It has seemed that possibly I could justify this addition to the long list of S. P. E. E. dissertations on educational policy on the grounds that it includes in the way of illustration an actual program which has been planned in accordance with the policy here discussed. It is thus my intention to outline the experience in terms of which my appraisal of engineering education has been made, and my objectives framed; to define the inadequacies of prevailing educational policies and programs, as I understand them, with respect to the development of intellectual leadership; and finally to describe a plan which remedies those inadequacies. In short, I wish to propose a readjustment of certain phases of policy and thus also of programs.

### *Background*

Although one's educational philosophy is of course influenced by reading and study, it is yet molded in its general form in the matrix of one's personal experience. In order therefore to make my point of view intelligible, it would seem essential that I indulge in a few personal references. These relate to certain phases of my professional experience which have had a definite influence in forming my views. I left college with a sense of the inadequacy of my training—a vague yearning for a better understanding of the basis for some of the engineering routines and techniques I had learned to carry out with reasonable facility. I had learned technical book knowledge well enough to reproduce it; I had learned how to solve special types of problems and how to carry out certain important routines. But something was missing. It was a genuine understanding of the *significance* of fundamental principles and concepts. In my later association with graduates of many other institutions I found that my college experience in this respect was not unique; it was, on the contrary, a common experience. It was not therefore characteristic of an institution but rather the result of a *system* of education.

Later in my professional practice this vague notion regarding my inadequacies became a conviction. There is one educational experience which has stood out above all others in forming my point of view. It was the gradual release and cultivation of such latent mental power as I possessed, by my being exposed repeatedly to the discipline of Steinmetz's mind. Within my limits, he taught me how to think. And this was the process: unable to solve a problem, I would go to Steinmetz for help. He would show me the way out of my difficulty. Now in doing this he did not tell me any new fact of book knowledge; he merely pointed out a principle of physics which, if applied, would tell me what I wanted

to know, and then he applied it. I already knew the principle; I could recite it; I thought I understood it. What I did not understand was that the principle would help me solve the problem. The simple fact is, I had not learned to analyze a situation in terms of general principles. Rather, I was looking for a formula and there was no formula; a general principle or concept was all that could help me.

I remember especially the first problems I took to him. One related to the heating of certain parts of an alternator. In a machine which I had designed, the heat did not flow from the armature copper the way I had planned. After talking to Steinmetz for a few minutes it became clear that my trouble was my inability to see the implications of the Law of Conservation of Energy and the Second Law of Thermodynamics. In another problem in those days I was trying with little success to determine the distribution of magnetic flux in a generator under the condition of short circuit. So as usual I went to Steinmetz. The outcome was the same; he merely pointed out that the application of the concepts of magnetic potential and of equipotential surfaces would solve the problem. And so on, time after time, I went through the experience of having him point out to me something I already knew but had not learned how to use. Finally, I came to be ashamed to "face the music." So when I got stuck and had the impulse to consult Steinmetz, a curious thing happened: I asked myself how he would look at the problem; then I looked at it that way and solved it. If this had happened only once, I should hesitate to relate it here; but it happened time after time. I thus gradually became able to stand on my own mental feet; I had, in other words, experienced an educational advance.

Another experience which has influenced my point of view relates to the training and trial of college graduates in industry. One of my responsibilities was to select and train a group of the most promising graduates available for leading positions in engineering in the large industry with which I was associated. In testing these men in examinations, in classroom, and on the job, I came to have in mind a definite pattern for the typical college graduate whom I have characterized elsewhere * as follows:

> From personal experience, extending over a decade, in examining and following the professional progress of very large numbers of electrical and mechanical engineering graduates from over a hundred engineering colleges, it is my studied observation that they have acquired at college notable facility in certain routine engineering techniques; that they have in memory a large body of engineering information; that their long drill and experience in careful measurement and numerical calculation have

* *Yale Alumni Weekly*, February 24, 1933.

engendered in them a quantitative sense, a profound respect for a fact, and habits of thoroughness, orderliness, and accuracy, all of which are distinctive attributes of a scientific, professional mind.

However, with all these recognized values, their college courses have left most of them at graduation mentally clumsy, relatively narrow in interest and perspective, and awkward in writing and speech. Their minds have not been sufficiently disciplined in straight thinking, and consequently they are lost when they encounter a problem which does not conform to certain special types. They are practically incapable of analyzing problems or situations in terms of general principles. They think narrowly in terms of special formulæ and specific cases. Moreover, under the pressure of time they have not developed a real interest in other vital aspects of life. Without an historical perspective, with little knowledge and almost no interest in the thoughts and lives of great thinkers in other fields, engineering graduates have tended to remain in the comparative isolation of technology. Now the sin of professional isolation is not confined to engineering; the same charge, it seems, might be leveled with justification at any of the other professions. But it becomes especially significant in the case of engineers because their technological advances have created, and will continue to create, a new world in which people have to live; and that world should not be patterned with reference to physical forces alone.

Now I realize that this is a very broad and critical statement. I should hope that it would not be interpreted as condemning as futile the carefully studied policies and programs of engineering education in America. I do not have to recall to you the great contributions which engineers who graduated from those programs have made toward the progress of technology. The simple fact is that in providing a training for the routine operations of engineering these programs at the same time have opened the *possibility* for the self-development of these other powers to which I have referred, even if that self-development has had to be achieved against odds and usually after graduation. The point is that if the objective is to provide educational preparation for *leaders* in the profession, then the development of the powers which characterize such leadership should not be left to chance amid difficulties, but should be purposely fostered.

### *Objectives*

The foregoing observations have given some indication of the influence which my professional experience before coming into the educational field has had upon my point of view. We are now ready to review the old fundamental question of objectives which has been the focus of much thought in recent months, as indicated by such notable studies as those by Dean Potter,* Secretary Wal-

* "Whither Engineering," *Mechanical Engineering*, January, 1934, pp. 1–7.

lace,* President Wickenden,† and Mr. L. W. W. Morrow.‡ One does not find unanimity of view in the published studies of which these are representative, but one does find in them a searching interest and a recognition of the growing importance of engineering leadership.

In reviewing the question we shall take the S. P. E. E. Report as the logical starting point. Its recommendations, as I have already indicated, seem to me adequate in the main. One wishes that in reference to training for the higher levels of professional service greater emphasis might have been placed upon the importance of a cultivated intellect; and moreover that this vital phase of professional service might have been more definitely identified, as I shall indicate later on. However, emphasis upon these aspects is clearly implied in most of the recommendations and here and there some explicit references are made; so in our interpretation of the Report these should not be overlooked.

The scope of engineering is defined by the Report by specifying three major types of service, as follows:§

1. The control and utilization of the forces, materials and energy of nature;
2. The organization of human effort for these purposes; and
3. The estimation of costs and appraisal of values, both economic and social, involved in these activities.

These fields of service can be broken down in another way. From the point of view of an educational approach it is convenient to classify service according to level, since appropriate educational programs for different levels are generically distinct. The S. P. E. E. Report also makes such a classification but it would seem to propose only two levels‖ in the sense here referred to: (*a*) technical expert and administrative, and (*b*) "auxiliary" or "secondary." These two classifications are further implied in "Objectives"¶ which I quote as follows:

1. The original dominating motive of engineering education was preparation for the higher forms of expert services detailed in the foregoing outline. Henceforth preparation for the higher administrative services of engineering should take coördinate rank. It should be recognized, how-

* "The Social Advantages and Disadvantages of the Engineering-Scientific Approach to Civilization," *Science*, January 5, 1934, pp. 1–5.

† "Engineering Education in the Light of Changed Social and Industrial Conditions," JOURNAL OF ENGINEERING EDUCATION, October, 1933, pp. 148–161.

‡ "Industry Demands and Engineering Education," *Electrical Engineering*, April, 1934, pp. 518–522.

§ S. P. E. E. Report, Vol. 1, p. 84.

‖ *Ibid.*, pp. 109–10.

¶ *Ibid.*, pp. 112–13.

ever, that the usual path of progress of the engineering graduate begins with subordinate technical activities.

2. The same general grounding is desirable for both the technical and the administrative activities in the engineering field, since the qualities of mind and habits of thought which are the most distinctive characteristics of the engineer are of more consequence in both realms than a book knowledge of either type of technique.

3. Distinctive training for both the technical and the administrative types of engineering activity should be provided but only after an adequate grounding in science and engineering fundamentals has been laid. There should be relatively little differentiation of the two types of training in undergraduate engineering curricula.

4. The auxiliary technical services and the minor supervisory and commercial activities associated with engineering are not recruited most effectively from the by-products of a program of professional training, nor are they adequately filled by using them as training assignments for men to be advanced rapidly to the higher types of engineering responsibility. These activities should be included in the objectives of a distinct, non-collegiate type of technical education, briefer, more intensive and more specialized than the programs of the engineering colleges.

Instead of the two levels of service proposed by the Report, I would suggest three, as follows:

I. Tertiary, routine technical and supervisory service, which is the "secondary" or "auxiliary" classification in the Report;

II. Secondary level, the service of the usual engineering practitioner or supervisor, in which the characteristic function is to carry on in usual engineering practice under general direction or according to precedent;

III. Primary or higher levels of professional service either on the scientific side, in industrial administration, or in the larger lines of public service. Here the characteristic functions are to establish new lines of thought and activity, to fix policy, and to direct.

What should characterize the educational programs designed to prepare graduates for entering these different fields of service? Before this question can be adequately answered another must be proposed and answered, namely, What should characterize the educational *results* of such programs? If we can specify the result we are seeking we shall be in better position to prescribe a program to attain it.

In the case of (I), the result should be the ability to do certain specialized routine operations. The answer to this phase of the problem, as specified above in the S. P. E. E. "Objectives," is the Technical Institute * program.

* "A Study of Technical Institutes—A Collateral Project to the Investigation of Engineering Education," Society for the Promotion of Engineering Education, February, 1931.

For (II), the training, whether for technical engineering, supervisory work, or both, should be tested by the graduating student's ability to understand and solve problems which have been defined for him in rather specific terms, and which are solvable by precedent, that is to say, by the application of the special knowledge, formulæ, rules, or techniques of his particular field; by his ability intelligently to carry out tests or investigations of a more or less standardized type, and to prepare reports upon them which are clear, orderly, and accurate; and by his ability otherwise to use the English language effectively. Moreover, he should, naturally, have a reasonable background of English literature and history.

For (III) it is different. The training for entering service in any phase of the upper levels of the profession should be tested by the student's mastery of the basic science and other fundamental knowledge underlying the technical side of his field; by the extent and character of his knowledge, both historical and scientific, relating to the social and economic side; by his ability to analyze situations new to him in terms of general principles, to draw rational inferences from given data, and to devise; and finally by his ability to express his thoughts logically and with a scholarly style.

These specified educational results imply the general character of the training required to cultivate them. There are primarily two features which distinguish between the training programs for (II) and (III). One is the extent of autonomous work; the other, the nature of the disciplines. For (II) very little autonomous work is indicated. The disciplines should lead to a reasonable grasp of the basic science and other knowledge underlying the formulæ, techniques, or methods the student has learned to apply; and should provide considerable drill in such applications. For (III), on the other hand, there should be a large measure of autonomous work. The disciplines should lead to a thorough mastery of the fundamental scientific and other knowledge underlying his field; and they should, moreover, be designed with a view to cultivating analytical and creative powers, an historical perspective, and clear, logical expression.

I would emphasize another point which has a direct bearing upon the objectives I am attempting to define. It is the importance of differentiating between the educational programs, on the one hand, and the students who pursue the programs, on the other. It is too much, of course, to hope for a Platonic perfection in which every student would be enrolled in the program best suited to his abilities, however desirable that might be. But what is even more hopeless is a single program that is appropriate for all abilities.

We should, first of all, set up the types of programs referred to, and then do what we can to get the best selection, recognizing both the difficulty of proper selection and the consequence of imperfect selection. From the point of view of progress of society and of the profession it is better to straddle the fence on selection than on educational program. Proper educational disciplines for the usual run of practitioners and for professional men in the higher levels do not mix well, especially in the later phases, and in my opinion great educational sacrifice is made when the two are mixed. It is better to have a few natural leaders handicapped by a training for (II), and a few natural practitioners handicapped by a training for (III) than to have all potential leaders not only denied the privilege of an appropriate educational program, but bored and stunted in their intellectual growth by pursuing a program which is inappropriate.

The foregoing paragraphs define general objectives, that is to say, the three major areas of engineering service as I would divide it; and they also specify correspondingly the general characteristics of appropriate educational programs. We come now to a more specialized consideration of the particular area in which the interest of this paper mainly centers—namely, that of the upper level (III). With special reference to this level I wish to discuss a few implications of the general objectives before presenting an illustrative program.

The first of these is the effect upon specialized undergraduate courses. The effect is practically to eliminate them. We are thus freed from the prevalent pressure, which rises in direct proportion to the extension of the field of engineering, to add yet another course to an already overloaded curriculum. Under the stated purpose, two highly desirable results follow. One is that the program can be devoted to fundamental disciplines; the other, that the total scheduled class time can be reduced to a level which is more consistent with that in other educational programs in the arts and sciences, thus leaving available time in which the student can pursue individual projects, give adequate thought to his work, and participate to a reasonable extent in extra-curriculum activities. The educational importance of lifting the incubus of specialized undergraduate courses cannot be over-emphasized.

Now this is not to be interpreted as meaning that specialized courses per se are educationally undesirable. The question is merely one of time and place. To include such courses in the undergraduate curriculum is to preclude those which are essential to our stated objectives, simply because the total time available is limited. Accordingly, the place for specialized study is in the

graduate program, or during professional practice. But even in graduate study, if I may digress for a moment, the primary purpose of a specialized course should not be for the student to learn merely the special subject matter and technique involved in order to become a practitioner in the particular field. There are two important reasons for this: in the first place, the student may never enter that particular field; and, secondly, the training of mere technicians is inconsistent with our objectives. Rather, the purpose of the specialized course should be primarily to afford an opportunity for the student to become acquainted with and disciplined in the scientific method of advanced work—in other words, an opportunity for him to bring to bear upon the problems of a specialized field both the scientific knowledge and habits of mind established in undergraduate work. If he learns the scientific method in this way, he will be prepared to apply it in whatever special branches of the field he may enter.

This leads to probably the most important point to be emphasized. Experience has demonstrated that a trained mind will make its way in new situations, even if the particular subject matter and techniques involved have not been learned in college. Everyone can call to mind numerous men who are eminently successful in fields not pursued in college. With an appropriate basic knowledge these specialized aspects can be learned by a trained mind with reasonable facility after college. The converse, however, is not so true. The man who has spent his formative years in college largely in acquiring information and learning special techniques is under an extremely discouraging handicap if later in the crowded hours of professional practice and without a guiding discipline he tries to learn how to think. Now of course there is thinking to be done in any specialized undergraduate course, and subject matter and techniques to be learned in any course designed primarily as an intellectual discipline. The crucial question is: on which of the two—thinking, or subject matter and techniques—is the primary emphasis to be laid?

It should be upon the thinking process. The various subject matters should naturally be chosen with reference to the professional focus toward which the program is directed, and to their aptness as material for developing logical and constructive thought. For instance, a prominent place should be accorded to mathematics and physics not as mere preparation for future specialized theoretical work involving these, although the outcome might be that in individual cases, but rather as a rigorous discipline in analysis —in the art of thought. And likewise on the social and economic side emphasis should be placed on *problems* with the same purpose

in view—namely, not merely to acquire some basic knowledge in these fields, but to provide a discipline in analyzing situations which are different from those on the science side in that they are not so technical in nature. My whole point here will be missed if it is not understood that the prime objective is a cultivated mind and not the covering of extensive ground of subject matter.

The second implication is the importance of *balance* in any educational preparation for constructive service. One of the greatest deficiencies of engineering courses in this country, in my opinion, has been the lack of cultural balance. Where such a balance has not existed the student's intellect has been literally starved for the vitamins of humane appreciation, thus leaving him with what might be called technical rickets—a wooden interest in matters outside his technical field. It might be mentioned incidentally that it is equally unfortunate that certain liberal arts courses, and even some professional, are culturally unbalanced the other way around. Such of these courses as eschew science and thus leave the graduating student without an adequate appreciation of either the scientific method or the dominating significance of science in modern life, cannot, it seems to me, be regarded as appropriate educational preparation for constructive service. In any case, we in engineering should insist upon providing such a balance.

The third point relates to the student's ability to think straight. There should be balance in discipline as well as in subject matter. Only half of the educational job is done when subject matter is mastered; the other half is disciplining the student's mind in applying the acquired knowledge. Straight thinking is not to be regarded as an incidental by-product of lectures and of those class exercises in which it is the purpose to impart and explain the meaning of information, and to test whether that information has been learned. Rather it is to be *achieved by the student* through his active participation under discipline in analyzing situations which are new to him and which involve deduction from some established generalization, the opposite process of establishing a rational inference from observed or given data, or the creative process of devising. Exercises to this end are those which provide an appropriate situation to be analyzed and a guiding discipline, and in which the student takes primary initiative.

An important distinction should be drawn between the mental process involved in such exercises, and that in the more usual ones in which, for instance, the student learns from a book or lecture how a formula is derived for some typical problem and then "solves" another problem of that type by substituting the proper numbers in the formula. In the latter case the principal element

of logical thought under the student's own initiative is the inductive process, elementary as it may be, of selecting the appropriate formula for the particular case. The rest is largely routine. The weakness of the usual educational method on the science side of engineering education is that it passes too lightly over the fundamental processes by which engineering routines are formulized, and dwells too heavily upon those routines. To apply a *principle* to the analysis of a situation—to reason out and then to specify in clear and precise English the conditions which must be satisfied in accordance with the principle—and finally to translate that set of conditions into mathematical form, together impose upon a student austere requirements of straight thinking that are hardly to be matched as a discipline of analytical powers or as a means of cultivating a scientific attitude of mind. This process of analysis ends with a solution in terms of quantitative results. An outline of this analytical approach is given in the Appendix. The distinction between the two mental processes referred to is much the same as the distinction between reasoning and repeating from memory; between being in an active and in a passive state of mind; between leading and being led; in other words, between the processes of a scientific mind and those of a routine practitioner's.

My fourth observation relates to the old educational theory which holds that full, precise knowledge must be acquired before anything further can be done about it. For instance, in music one must learn all the notes, time, and scales before attempting a tune; in art, the knowledge of perspective and the technique of drawing and copying, before an attempt can be made at composition; and in engineering, all the mathematics through calculus and all the fundamental physics before making a serious attempt at constructive thinking. If one spends too many years merely in getting ready, however, his mind becomes regimented; freedom of thought disappears; the creative spark is extinguished.

This older view is passing, thank Heaven! There is little to be said for it apart from the Spartan torture which it inflicts. In the newer and saner approach, the different phases of learning are developed together. In music, for instance, the child starts immediately on a tune, and discipline and precision are developed conjointly with his ability to play; and the plan works. In art the case is quite as striking. On my learning that for ten years, excepting one, some student of the Yale School of the Fine Arts had received the coveted Prix de Rome, I inquired regarding the teaching method. I learned that on the first day a student enters the Department of Painting he is started along two parallel disciplines; he is given a simple problem in creative composition and is started

on the elements of factual representation. These disciplines are thus continued with decreasing time upon factual representation and correspondingly increasing emphasis upon creative composition. Ultimately the two are merged. In engineering the same general principle should be followed. For example, when a new principle of physics is taken up, its implications should be explored by the student. He will not be able to go very far the first time, or the second time. Guiding the student in this is to the teacher a long, dreary process, but there is, to my knowledge, no other way of accomplishing the purpose. While the old idea referred to above still persists in most teaching of basic science, one looks forward hopefully to a time when more thinking may be done in the early stages and when there will be less rush merely to cover ground.

The final aspect that I wish to emphasize is the ability to write well. The importance of this in professional practice in the upper levels is too obvious to be argued. Although this alone might be sufficient to warrant great emphasis upon such ability, there is yet another equally important reason, namely, the connection between good writing and good thinking. There is no better discipline in straight thinking than the insistence upon a clear and logical thought structure in written analyses or expositions. These should not be mere description or paraphrases of some published work, but the student's own analysis of a question or problem in the light of his purposeful reading. A written statement is a faithful mirror of the state of one's thoughts; and a discipline which brings about a rearrangement of material and phraseology into a logical and unified form, implies also a corresponding readjustment of thoughts in one's mind. Hence I regard such a discipline as essentially complementary to the physics-mathematics discipline already referred to.

Thus, to summarize: An undergraduate course in engineering should train students to *become* engineers, and not train engineers; it should develop a foundation for later professional specialization, yet it should constitute, at the same time, a balanced education. It should thus be a bilateral program involving, on the one side, the mastery of the fundamental principles of the physical and mathematical sciences and a rigorous discipline in reasoning in which these principles are applied to the analysis of problems; and on the other, the acquirement of a basic knowledge of English, history, and the pertinent social sciences, and the application of such knowledge to social and economic problems. Thus the prime objective pervading and unifying the whole should be the development of the power of analysis and understanding, and the cultivation of a scholarly attitude and style.

## II. Program

These basic thoughts underlie our program in electrical engineering at Yale. I shall now discuss that program. The curriculum embodies two general lines of study which I have called *primary educational stems*, implying growth from a main educational trunk. All we can hope to do at college is to engender and cultivate such a primary growth. From each of these primary stems established in undergraduate years will later issue secondary specialized branches in graduate work or early professional practice, and, still later, further extensions to full foliage, thus forming at maturity a balanced intellectual growth.

One of these lines of study is the *Science Stem;* the other, the *Social and Economic Stem.* Approximately two-thirds of the student's educational time is devoted to the Science Stem, one-third to the Social and Economic. These are illustrated in the accompanying diagram. It may be mentioned incidentally that the bilateral nature of this program is entirely consistent with the S. P. E. E. recommendations * for a "band" of science studies and a "band" of humanistic studies.

### *Science Stem*

The mastery of basic science has been specified as a requisite for the Science Stem. This implies the necessity of (*a*) a careful check-up in the Junior year as to the extent and depth of the scientific learning acquired in the Freshman and Sophomore years; (*b*) a systematic remedy of deficiencies and the organization of such learning into a unified knowledge; and (*c*) an extension of the student's knowledge of mathematics and physical science, especially electrical, to include those more advanced phases which are regarded as basic to the field of electrical engineering. Part of this advanced knowledge is merely extension of ground already covered in the Freshman and Sophomore years, as in the case of mathematics and physics; and part is largely new, such as Thermodynamics and Metallurgy. The former extensions are effected incidentally as occasion arises in connection with advanced physical problems in the electrical engineering courses, and the latter are taught as separate subjects, as indicated in the diagram.

I shall now translate the foregoing aspects of the Science Stem into terms of courses. There is a continuous and progressive relationship between the courses of preparation in science in the Freshman and Sophomore years, and the courses of application in the Junior and Senior years. Indeed, the curriculum is constructed

* S. P. E. E. Report, p. 87.

THE ELECTRICAL ENGINEERING CURRICULUM

| Science Stem | | | Social and Economic Stem | | | Suggested Electives and Other Information |
|---|---|---|---|---|---|---|
| MATHEMATICS | CHEMISTRY | DRAWING | ENGLISH | NON-TECHNICAL ELECTIVE | FRESHMAN | Electives: History or a foreign language. Students who anticipate graduate work should elect German or French.<br>Introduction to Engineering, E 10, a course of seven lectures and six optional meetings, is usually taken in the Freshman year.<br>Military or Naval Science may be taken as an additional subject.<br>Plane Surveying, CE 10s, is taken at Yale Engineering Camp in the late summer preceding the Sophomore year. |
| MATHEMATICS | PHYSICS | MECHANICS | | ECONOMICS | SOPHOMORE | Normally there are no electives in the Sophomore year. Where it is desired to continue a foreign language begun in the Freshman year, this may be done in special cases by postponing Economics to the Junior year.<br>Military or Naval Science may be taken as an additional subject.<br>Mechanical Technology, ME 10s, is taken in the late summer preceding the Junior year. |
| ELECTRICAL AND GENERAL ENGINEERING | | THERMODYNAMICS | ENGLISH | NON-TECHNICAL ELECTIVE | JUNIOR | Electives: Students with a C average or better may elect (and are advised to do so) either EE 35* or AE 35.** Other suggested electives are: Sociology 10, Sociology 11, Philosophy 37, Industrial Physiology 65, Government 11, Military or Naval Science.<br>Electrical Engineering Laboratory, EE 39s, is taken in the late summer preceding the Senior year.<br>* "Elective projects" course described in the paper.<br>** Human Relations in Industry. |
| | STRENGTH OF MATERIALS / METALS AND ALLOYS | SEMINAR | | NON-TECHNICAL ELECTIVE | SENIOR | Electives: Students with a C average or better in the Junior year are advised to elect EE 45.* Other suggested electives are the same as those for the Junior year, excepting that if Sociology 10 is taken in the Junior year, Sociology 20 may be elected in the Senior year; also Industrial Management.<br>Seminar, EE 41: the presentation, both written and oral, of studies relating to the social and economic aspects of technology, and to the history of science and engineering.<br>* Same as EE 35. |

← 15 Hours per Week →
(30 credit hours per year)

to the greatest practicable extent on the principle that only that subject matter be included which will later be used in course. In each of the last two years of the Science Stem there are only two courses in electrical engineering, and these are closely coördinated. They extend through continuously, as far as purpose and character of work are concerned, from the beginning of the Junior to the end of the Senior year. The primary purpose of one is to extend the student's knowledge of electrical science; of the other, to unify and coördinate previously acquired scientific knowledge—viz., mathematics and those fundamentals of physical science which are basic to the field of electrical engineering—and to apply it under rigorous discipline to the analysis of problems.

Stated more specifically, in the one course primary emphasis in the Junior year is upon fundamental theory relating to circuits and to electric and magnetic fields; and in the Senior year, upon further extension and application of such theory in connection with circuit *systems*, and upon the introduction of cost as a factor in the engineering problems considered. Examples of the circuit systems considered are the simpler forms of direct current and polyphase electrical apparatus, transmission and distribution circuits, and tube circuits. In the other course, primary emphasis in the Junior year is upon a review and integration of previous work in physics relating to energy in three forms—mechanical, thermal, and electromagnetic. This revitalized knowledge is then applied to physical problems. These are analyzed in terms of basic principles such as the Law of Conservation of Energy, Newton's Laws of Motion, D'Alembert's Principle, Principle of Superposition, the Laws of Thermodynamics including those of heat flow, Coulomb's, Ampere's and Kirchhof's Laws, and the laws of electromagnetic induction. In the Senior year, the student's work in this course extends along the same lines as in the Junior year, and culminates in the second semester in comprehensive projects of a truly engineering character which involve the fundamental aspects of previous work in all courses.

Additional important features of these two courses are as follows: the laboratory exercises are coördinated to the greatest practicable extent with the theoretical work; a liaison instructor assists in maintaining unity of thought in the two courses; class work is largely seminar in character; individual differences among students are recognized in the class programs, thus keeping the class stimulated at the highest practicable level of accomplishment, especially the outstanding men; a comprehensive examination, now planned, at the end of the Senior year will set the standard and establish a focus for the entire program; and essential extensions

in knowledge of mathematics, mechanics, and physics beyond that acquired in the first two years are effected in course at the time they are needed in connection with the physical problems analyzed. Such extensions include in mathematics, algebra of the complex number, linear differential equations, vector analysis, and elementary phases of operational calculus; in mechanics, essential aspects of advanced dynamics; and in physics, advanced electromagnetism, electronics, and phenomena of gaseous conduction.

### *Social and Economic Stem*

As in the Science Stem, here also the fundamental requirements for the program are, first, a provision for an appropriate knowledge which may form the basis of constructive thinking; and secondly, a continuing and rigorous discipline in the rational analysis of situations in terms of that knowledge. It is thus not sufficient merely to provide a program which presents selected material to be learned; it is essential, in addition, to guide the student in its adequate interpretation and require him independently to apply it. As the requirement of application is, of course, the most difficult, it must be introduced gradually and given progressively greater emphasis as the course advances. For instance, in the early courses in such subjects as history or economics in the Freshman and Sophomore years it seems necessary at the present time at least that the greater part of the emphasis be placed upon the requirement and interpretation of basic knowledge; yet I believe that its application in simple situations could and should be started more definitely in these early stages. In any case this should be carried out in a major way in Junior and Senior years. And, finally, whatever appreciation of literary style may have been acquired in earlier work should in these later years find expression, stimulation, and further cultivation.

As a specific illustration of the type of program which meets these requirements I shall outline a new elective course, designated as "Elective Projects," which has been developed in the Electrical Engineering Department at Yale. The course is indicated on the diagram as EE 35 and EE 45. During the past two years it has been conducted with a half dozen students on an experimental basis with promising results. The general plan is cyclic, each cycle representing the treatment of a problem in four steps: first, the practically independent study of a problem relating to some social or economic aspect of engineering activity or of technological progress; second, the preparation of an essay setting forth the analysis and conclusion; third, the defense of the solution in a

small seminar; and, finally, presentation of the problem and solution as a speech to a large group.

More specifically, in the first step the students are required to read a few books in order to extend the background from which to select a problem. This is required because it was found that such background as they had was hazy; it needed clarification and extension. In this particular year the books assigned were Adams' "Epic of America," Cheyney's "Industrial and Social History of England," and a third chosen by the student from a shelf of about a dozen carefully selected volumes, the student's choice being made presumably in accordance with the interests stimulated by the previous books. The problem, which is then selected with the approval of the instructor, must be one of sufficiently limited scope to be treated in, say, fifteen hundred words. When the problem is defined, an advisor is selected. He may be any faculty member in the University in whose field the chosen problem lies, and who is willing. The student discusses the problem with him in a preliminary way and thus receives stimulation and advice as to reading. This conference may take only an hour or so, but what an important hour! Then the student is on his own. There are no formal classes; only conferences with the instructor once every week or two. The student's time—about nine hours a week—is spent in reading and study. As he approaches a solution he may again consult his advisor, and, as usually happens, one or two others who he thinks can help him settle a troublesome point. When the study is completed and a conclusion reached and justified, he is ready for the second step.

This is the careful preparation of an essay presenting the analysis. Here is an occasion for constructive exercise both in logical thinking and clear expression. The essay is not accepted until it shows evidence of both, and this usually requires repeated trials. On this first essay a great amount of time is necessarily spent on the mere mechanics of expression, of logical arrangement and accurate and clear phraseology. Incidentally, it is noteworthy that there is a striking and significant similarity between the student's awkwardness in applying, on the one hand, the principles of rhetoric and even of grammar, and, on the other, the principles of physical science. Before the Junior year he has presumably learned both, but their significance in giving direction to his thought is extremely slight. It seems to require almost a year in either case to get a pattern of approach established. And these essays form the basis of a discipline in this respect.

The third step is an extremely important one. The solution must be defended in a small seminar in which the thought struc-

ture and the clarity of phraseology are criticized. In these seminars the evident intellectual stimulation of the students—and of the instructor as well!—is one of the most encouraging results of the experiment.

The fourth step is preparation for the oral presentation of the analysis, and the presentation itself. Usually an essay is not in appropriate form for a speech; it needs some modification. Moreover, effective oral presentation requires plan and drill. After such preparation, the speech is made to a larger group.

Then a new cycle is started. It is planned that three problems will be thus treated during the year, each successive problem being of about twice the extent of the one preceding.

The nature of the problems studied may be gleaned from the following titles:

Clearance of the Slums
A New Valuation of the Worker
The Effect of Technology upon Religious Thought
Is the Machine Leading Us to Socialism?
NRA: A National Recovery or Revolution?
What are the Trends of Modern Architecture?

There are obvious practical difficulties in the way of developing such a program. How many busy professors outside the School of Engineering are willing to be thus bothered? Are enough consultants available, in addition, for the time-consuming job of criticizing the composition of the essays? What portion of the students have the capacity for such independent work? Experience indicates that none of these is insuperable. The response from the professors who have thus far been approached has been most encouraging. Without exception they have been willing and some of them even enthusiastic. The evident reasons for this response are that the student has a definite problem about which *he* is taking the initiative; and the demands on the professor's time is small. What it means to the students to have such a broad range of talent available to them is beyond estimate. As to guidance in writing, this becomes more of a routine matter for the instructor than passing final judgment upon the work as a whole, and indeed it may be done by a different person; but it is essential to the plan that it be well done. Here again the total time per student required of an instructor, since there are only three essays per year. And, finally, it is proposed to solve the problem of capacity by admitting to the course only those students who have made grades of C or better in all preceding work. It thus appears that there is no practical reason why the plan cannot be fully developed; and if

this does occur, and the better students spend some nine hours per week through two academic years in such activity, it seems reason-

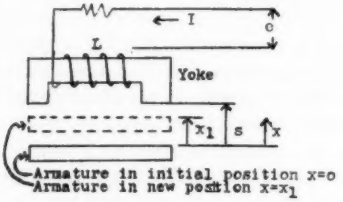



FIG. 1.

able to suppose that they will achieve the objective which has been set for them.

## APPENDIX

### A Pattern of Approach in Deductive Analysis

(An example from class material)

| | |
|---|---|
| I. Define the Problem. | I. |
| *a.* Definitive description of the situation to be analyzed. Make a sketch. | *a.* An armature is arranged with respect to an electromagnetic yoke so that when released it will move toward the yoke under the influence of magnetic attraction, against the force of gravity. The armature is constrained to move in pure translation only. See Fig. 1. |
| *b.* Statement of result desired. | *b.* It is desired to determine the velocity of the armature when it has reached any new position. |
| II. Specify: | II. |
| *a.* The fundamental principle which is to constitute the basis of analysis. | *a.* The Law of Conservation of Energy. |
| *b.* Simplifying assumptions. | *b.* 1. The current through the electromagnet remains constant.<br>2. Frictional resistance to motion is neglected.<br>3. The inductance of the electromagnet is inversely proportional to the air gap between yoke and armature. This is based upon an hypothesis of parallel flux lines traversing the gap, in which all of the magnetic reluctance is assumed to be concentrated. |
| III. State in precise English the conditions which must be satisfied in the particular situation according to the fundamental principle. | III. *The work done on the armature by the magnetic force must equal the gain in potential energy of the armature plus the gain in kinetic energy.*<br>[There are other possible correct statements. For instance: *The energy supplied to the system from the electrical source must equal the increase in the energy of the system plus the energy dissipated.*] |
| IV. Translate III into mathematical form. | IV. |
| *a.* Specify a coördinate system. | *a.* Let $x$ be a coördinate measuring the distance in cm. of the armature from the initial position in the direction of motion toward the yoke. |
| *b.* Specify notation. | *b.* Let $e$ = voltage across coil, in abvolts.<br>$f$ = magnetic force on armature, in dynes.<br>$g$ = acceleration of gravity, in cm./sec.$^2$ |
| *c.* Express III mathematically. | |

$I$ = current through coil, in abamperes.
$L$ = inductance of coil, in abhenries.
$M$ = mass of armature, in grams.
$r$ = resistance of coil in abohms.
$s$ = initial distance of armature from yoke in cm.
$t$ = time, in seconds.
$v$ = velocity of armature, in cm./sec.

Let the new position of the armature at which the velocity is desired be $x_1$.
Let $L = L_0$ at $x = 0$
$L = L_1$ at $x = x_1$
$t = 0$ at $x = 0$
$t = t_1$ at $x = x_1$
$v = v_1$ at $x = x_1$.

c. By III

$$\int_0^{x_1} f dx = Mgx_1 + Mv_1^2 \text{ ergs.}$$

[ Or from the alternative statement in III,

$$\int_0^{t_1} eIdt = (\tfrac{1}{2}L_1I^2 - \tfrac{1}{2}L_0I^2) + M_gx_1 + \tfrac{1}{2}Mv_1^2 + \int_0^{t_1} I^2rdt. \ ]$$

V. Solve.

V. By assumption 3,

$$L = \frac{B}{s - x},$$

where $B$ is a constant which can be determined from data on the device.

From previous work

$$f = \tfrac{1}{2}I^2\frac{dL}{dx} = \tfrac{1}{2}I^2\frac{d}{dx}\left(\frac{B}{s-x}\right) = \frac{1}{2}\frac{I^2B}{(s-x)^2}.$$

Thus

$$\int_0^{x_1} f dx = \frac{I^2B}{2}\int_0^{x_1}\frac{dx}{(s-x)^2} = \frac{I^2Bx_1}{2s(s-x_1)}.$$

Substituting in expression III*c*,

$$\frac{I^2Bx_1}{2s(s-x_1)} = Mgx_1 + \tfrac{1}{2}Mv_1^2$$

or

$$v_1 = \sqrt{\frac{I^2x_1}{Ms}\frac{B}{(s-x_1)} - 2gx_1}$$

or, solving the alternative equation of IV$c$,

$$c = \frac{d}{dt}(LI) + rI = I\frac{dL}{dt} + rI,$$

since by assumption 1 the current is constant. Thus

$$\int_0^{t_1} eIdt = I^2\int_{L_0}^{L_1} dL + \int_0^{t_1} I^2 r dt = I^2(L_1 - L_0) + \int_0^{t_1} I^2 r dt.$$

Substituting in the alternative equation IV$c$ and cancelling the $I^2r$ term on both sides,

$$I^2(L_1 - L_0) = \frac{I^2}{2}(L_1 - L_0) + Mgx_1 + \tfrac{1}{2}Mv_1^2.$$

Substituting $L_1 = \dfrac{B}{s - x_1}$ and $L_0 = \dfrac{B}{s}$ and solving for $v_1$,

$$v_1 = \sqrt{\frac{I^2 x_1 B}{Ms(s - x_1)} - 2gx_1},$$

which is exactly the same result as obtained above from the first statement.

VI. Check results in terms of boundary conditions and dimensions, and discuss the probable effect of assumptions on the accuracy of results.

VI. If $x_1$ is taken as zero, $v_1 = 0$ as it should be, since the armature was taken as starting from rest. As $x_1 \to s$, $v_1$ becomes infinitely large, as would be expected if the assumed expression for inductance held as $x_1 \to s$.

(See discussion of assumptions below.)

Dimensional check:

Let the dimensions be represented as follows:

$[\mathfrak{L}]$ length
$[M]$ mass
$[T]$ time
$[L]$ inductance
$[I]$ current.

The expression for $v_1$ may be checked dimensionally, recognizing that $L_1 = B/(s - x_1)$, thus $[B] = [\mathfrak{L}]\,[L]$ and

$$\left[\frac{\mathfrak{L}}{T}\right] = \sqrt{\frac{[I]^2[\mathfrak{L}]\,[\mathfrak{L}L]}{[M]\,[\mathfrak{L}]\,[\mathfrak{L}[} - \left[\frac{\mathfrak{L}}{T^2}\right][\mathfrak{L}]}.$$

But $[I^2L] = [\text{energy}] = [M\mathfrak{L}^2/T^2]$.

Thus,

$$\left[\frac{\mathcal{L}}{T}\right] = \sqrt{\left[\frac{M\mathcal{L}^2}{T^2}\,\frac{\mathcal{L}^2}{M\mathcal{L}^2}\right] - \left[\frac{\mathcal{L}^2}{T^2}\right]} = \sqrt{\left[\frac{\mathcal{L}^2}{T^2}\right]}.$$

Assumption 1, of constant current, would be true if the voltage $e$ were caused to vary in the proper manner by a regulating device. If the source of voltage is a battery, the assumption is approximately true if the time constant of the electric circuit is small compared to $t_1$.

Assumption 2, the neglect of friction, introduces only a slight error if the force of friction is small compared to the magnetic force.

Assumption 3, regarding the form of the inductance function, is a good approximation over a limited range of air gap. Thus the expression obtained is not accurate when $x_1 \rightarrow s$ nor when the initial air gap is so great that the flux lines may no longer be considered as parallel.

# LIBERAL PURSUIT OF ENGINEERING STUDIES

By GORDON M. FAIR

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The title of this paper calls to the author's mind the educational genius of Charles William Eliot, President of Harvard University from 1869 to 1909. For it was in the first decade of Eliot's administration that introduction of the elective system of study was carried to completion in Harvard College. Its accomplishment was foreshadowed in his inaugural address, from which the following may be quoted: "A university must be indigenous; it must be rich; but above all it must be free. The winnowing breeze of freedom must blow through all its chambers. It takes a hurricane to blow wheat away. An atmosphere of intellectual freedom is the native air of literature and science." In the half century that has passed since the elective system had its inception at Harvard most of our educational institutions of higher learning have accepted it in some form or other in their divisions of arts and sciences and some in their graduate and professional schools as well. It has indeed become part of the American system.

With this heritage it is understandable that the Faculty of Engineering at Harvard should long have looked to ways and means for applying the tested methods of the elective system to the study of engineering subjects. A first step in that direction was taken many years ago by the introduction into Harvard College of a group of courses in the fundamental engineering sciences and the admission of college students to concentration in this field. At the present time the work offered in Engineering Sciences in the College is equivalent to ten * full courses and includes descriptive geometry, mechanics, thermodynamics, hydromechanics, surveying, electricity and the theory of structures. This group of subjects, together with rich offerings in mathematics, physics, chemistry and geology, more than covers the first three years of work normally asked of students in engineering schools. Inclusion of engineering sciences as a field of concentration in Harvard College signifies the recognition by the Faculty of Arts and Sciences of the cultural value of basic training in engineering, a principle long advocated by engineering teachers. Conversely, it is an acknowl-

* The number of courses required for graduation from Harvard College is sixteen.

edgement by the body of engineering teachers in charge of instruction in this field that basic training in engineering can be given outside the walls of an engineering school as such and that the rigorous training in sound reasoning which it provides may well serve as preparation for the learned professions, for business, or other life pursuits. While the elective system permits students, especially those looking towards engineering as a career, to concentrate fairly heavily in engineering sciences and related subjects, they are generally not encouraged to confine their interests to this field alone during their undergraduate years. They are cautioned by their advisers to develop a broad base of interests; to acquire ability to express themselves in correct and effective English; to gain familiarity with one or two foreign languages and have more than a superficial knowledge of the history, literature and current problems of significant countries and races; finally, to take at least an introductory course in economics, both for subsequent study of industrial and administrative problems and for the comprehension of the present social organization which it affords. By electing engineering sciences as his field of concentration in the College, the student may test his aptitude for a career in engineering by convincing himself of his liking and fitness for the work of the profession. At the same time he is made to realize that if he wishes to enter this profession, his broad cultural background should equal that of the other learned professions.

Turning our attention more specifically to the student who expects to become an engineer, it should appear from the foregoing that a guiding reason for introducing the discipline of engineering sciences into Harvard College was the general feeling of the Engineering Faculty that engineering as a profession had come of age and that schools of engineering should "keep pace with the march of a more and more complicated civilization and help to guide it" by graduating men of broad vision fully cognizant of the social and economic implications of their profession; in other words, by placing the Engineering School on a graduate basis. In this connection we may well turn to a page in Henry James' biography of Eliot (p. 261) in which he comments upon the status of the professional schools at the time that Eliot entered upon his presidency."

"In America in 1870 the ministry, law, medicine, and teaching were the only established professions. Nobody had yet thought of devising a special course of instruction for teachers. Engineering in its various branches, and architecture, although barely beginning to count a sufficient body of practitioners to claim recognition, were being taught by a number of new 'scientific' or 'technolog-

ical' institutions. They were forward-looking and unhampered by tradition; but they could find almost no teachers whom experience had prepared for their special work, almost no textbooks, and practically no apparatus. The schools that had long existed to fit young men for the ministry, medicine, and the law, whether at Harvard or elsewhere in America, were contenting themselves with a lower standard of accomplishment than they had aspired to during the first third of the century. In a measure their decline had been a consequence of poor administration. But it was symptomatic of a general decline of the level of culture in the learned professions; and that, in its turn, was but one of the manifestations of tendencies that had been modifying American society widely. After the time of Andrew Jackson and during the opening of the West, the social tone became younger and more crude than it had been, while the men who remembered the establishment of the Constitution enjoyed influence and power. The breakdown of the older authoritarian traditions was accompanied by changes in politics and manners as well as in the professions." Into these troubled times engineering education was launched by new scientific or technological institutions, taking their plan of study from Continental European examples and superimposing them on an American, not Continental European, system of primary education. The country, as pointed out by James, was extending its frontiers to exploit its natural resources and develop its industries. It was imperative to supply men capable of solving the immediate problems of this pioneer age; it was important to get things done; jobs were plentiful, and the ever-increasing number of engineering graduates was readily absorbed. The learned professions "were contenting themselves with a lower standard of accomplishment than they had aspired to during the first third of the century." Small wonder that under these circumstances there was little thought of predicating the professional training of engineers upon previous college education as would have been done if the broad principles of Continental European training had been conclusively followed. It may seem strange that Eliot did not include in his campaign for "Professional Standards" in the ministry, medicine and the law the setting up of professional standards for engineering as well, unless we appreciate the spirit of service to country and humanity which motivated him at all times. The need of the hour was for men and more men trained in the rudiments of science. Engineering, at Harvard, as a result was retained on an undergraduate footing while the learned professions were gradually returned to their proper educational position.

To-day the picture has changed: the frontier has been con-

quered, engineering needs, while as great, are not so obvious as they were, and jobs for the rank and file of engineering talent are no longer plentiful. This situation in itself might seem discouraging to the pursuit of engineering as a profession. It should not be so to men of broad education and vision whose talents lie definitely in engineering. Indeed it is the opportunity to renew the profession in much the same way as was done in the ministry, medicine, and the law half a century ago.

The Graduate School of Engineering at Harvard has recently been set up with these thoughts in mind. The fixed curriculum which characterizes undergraduate schools of engineering does not exist in the Graduate School. Students are permitted to develop their own programs of study under guidance; providing these programs show definite purpose and include a sufficient amount of work of advanced character, they are accepted by the School. The essential requirement is that the student shall apply himself wholeheartedly to the mastery of professional subjects so that he may develop habits of study and thought that will enable him to tackle new as well as every-day engineering problems in a sound and effective manner, whether or not he has studied the specific subject matter in school. This freedom of election recognizes that the method of the students' to-day is not necessarily the method of the practitioners' tomorrow and that the acquisition of professional knowledge has only its inception in the academic environment. Advantages gained incidental to the free choice of studies are the acceptance of full responsibility by the student, his careful consideration of what is best for him to do, and the attitude which he will take towards work because he himself has determined upon his task. Finally, from the standpoint of educational certification, it is more important to determine what sort of man has studied engineering subjects than what sort of subjects have been studied by a man. Again in the words of Eliot: "For the individual, concentration, and the highest development of his own peculiar faculty, is the only prudence. But for the State, it is variety, not uniformity, of intellectual product which is needful."

Although the plan of liberal education for engineering that has been outlined has been formulated on the basis of placing the professional training of engineers in the hands of a graduate school, it can, in the author's opinion, be cut to the pattern of undergraduate engineering schools with some promise of having the training of engineers keep pace with the march of a more and more complicated civilization and help to guide it. In a world sorely beset by regimentation of thought and action on a scale that has never been witnessed before, it would be well if engineering schools

returned to their primitive state of being "forward-looking and unhampered by traditions." The worst of these traditions, in the author's opinion, is the fixed curriculum no matter how many required "cultural" subjects it may contain. Only by throwing the chambers of engineering schools open to "the winnowing breeze of freedom" can we expect to meet our obligations as leaders of thought in the great and learned profession of engineering, to the ideals of which we as teachers subscribe. "It takes a hurricane to blow wheat away."

# SLIDE RULE PRACTICE AS AN INTEREST FACTOR IN ENGINEERING DRAWING

By H. M. McCULLY,

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The recent improvements in slide rule design and manufacture have given the engineer an instrument which for range of usefulness, precision and speed is so far in advance of those in use only a few years ago that only those in close contact with present-day practice appreciate the enhanced value and prestige of the slide rule as part of an engineer's equipment. It is indeed unfortunate that so many of our teaching colleagues have not kept themselves informed of the increased usefulness of such an essential element in the educational program of present-day students. This, of course, has been partly induced by the opinions which these men have formed on the basis of the rules which were available at the time they were students. They do not recall such an instrument as having been an effectual aid in their own mastery of the problems of the engineering curriculum. It has therefore not loomed so prominently on their educational horizon, and they have devoted their efforts to eliminating student workload difficulties in other ways. I think that there is beyond any question of doubt an increasing use of the slide rule by engineering teachers, but on the other hand, I feel reasonably safe in making the assertion that a great many of our teachers who should use the slide rule do not do so.

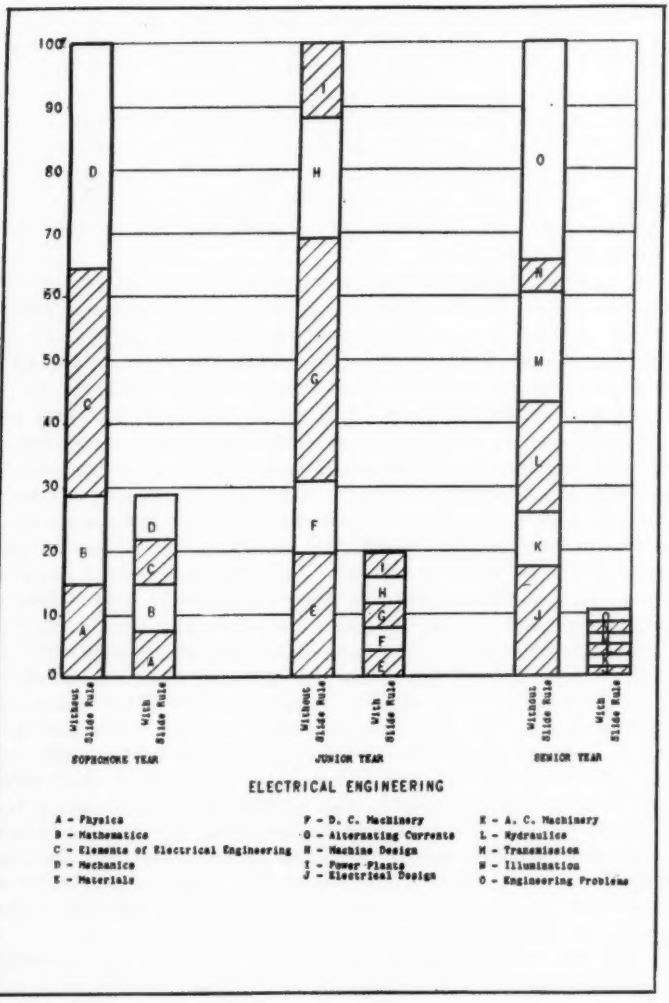
Many of us are perfectly familiar with the application of the slide rule to our own particular subjects, but few, if any, of us have ever made a complete survey of all the subjects in the engineering curriculum in connection with which a student might use a slide rule. Consultation with professors and instructors of various departments concerning the advisability and the extent to which they feel this instrument enters into successful work in their courses will be very illuminating. Quite commonly, the statement is made that under the present set-up in their courses, the amount of problem work, and the way in which they write examinations, tests, etc., the ability to use the slide rule is an essential factor in an engineering student's training. As a matter of interest, we conducted such an investigation of the various courses of the curriculum in an attempt to arrive at a definite idea of just how much

use an engineering student could make of a good rule and what effect, if any, it might have on the successful prosecution of his educational program. The results were greatly influenced, of course, by the extent to which mathematical calculations entered into a general or special curriculum. Two time periods were compared, first, the amount of time necessary to find an answer to a given problem when the necessary calculations were made by the usual logarithmic method, and second, when the calculations were made by means of the log-log or similar type slide rule. The proportion of time devoted to problem work in any given course was then involved in the calculation. These estimates were based, first, on the estimates of capable teachers of the different subjects, second, on the estimates of graduates from these courses, and third, actual performances of two different students, one working the problems by the logarithmic method and one by the slide rule method, were compared.

It must be recognized that any figures in terms of percentages for these results must at best be a somewhat broad approximation. This is true on account of the varying speeds at which different individuals work in calculation, and most important, their judgment as to how far out they should carry mathematical calculation. It is unfortunately very true that at the beginning of their program engineering students do not have the proper conception of the real meaning of significant figures and their relationship to the term, "percentage of error." They are all too prone to spend precious time, multiplying figures which might be dropped without decreasing the validity of their calculations in connection with given formulae. The results are also influenced by the extent to which students concentrate, the facility with which they determine basic formulae, etc., and the ease with which they are able to repel external interruptions in periods of mental abstraction. On the basis of this, a series of charts was drawn. They compared the total amounts of time that a student used by the logarithmic method and by the alternate slide rule method. The charts, of course, indicated very decided advantages in favor of the slide rule method of calculation. An encouraging feature of these charts was their general agreement when plotted from data arising from different sources and different people, but it might be well to emphasize that in terms of statistical practice, the data are somewhat limited. However, it is hoped that upon inspection of the chart and comparison with your own experience, you will in general be inclined to agree with the comparisons shown.

The chart for electrical engineering, which is very typical, is reproduced below.

Following this study, the idea of a regularly organized course in slide rule was referred to the membership of the student honorary engineering societies of the country through the medium of a questionnaire which included among others the following questions:



1. Were you able to use an engineering slide rule at the time you entered college?
2. Did you master the rule by self-instruction?
3. Were you given a regularly scheduled course of any length as a part of your curriculum?
4. Would you consider such a course of value to freshman engineering students?

I do not think that there will be any question raised as to the acceptability of the opinions of such a group, comprising as it does the most conscientious and successful portion of our student bodies. The response as one might expect was exceptional in terms of percentage and promptness of replies. The answers confirmed the natural assumption that members of engineering honoraries would master the slide rule very early in their educational program. It was interesting to note that with the exception of those few students who had mastered the slide rule before entering college, the answers to the questionnaire indicated that the membership of the engineering honoraries was practically unanimous in favor of a definitely organized course in slide rule practice for engineering students in the freshman year.

One other point of considerable speculative interest was the reaction of prospective freshman students to the slide rule as a required subject. When two different entering classes were questioned about their attitude on this subject, the results were indeed surprising. They were very much in favor of it. May I digress for a moment to speak of certain aspects of the entering student's conception of engineering education which are commonly neglected. May I say that I do not believe that we are playing exactly fair with the young men who come to us with the expressed desire of becoming engineers. It is unfortunate that our attitude toward young men who wish to enter the engineering profession seems to be almost one of negation. I feel that a young man who has met his entrance requirements, who has presented himself at an engineering institution and has paid his fees has given a sufficient guarantee of his interest and that we should do all in our power to sustain him. Many freshman curricula seem to have lost sight of certain psychological and, particularly, emotional factors which can be made to play a very desirable and important rôle in the development in the character of engineering students.

It should be remembered that in a great many cases the freshman student has recently passed through not only a rather exalting high school graduation experience, but also through an orientation week, both of which have stimulated his anticipation of great things to follow immediately. After the exciting week of regis-

tration, our freshman finds himself face to face with a program of study and experience which upon acquaintance becomes very significantly similar to what he feels was accomplished in high school. The new program lacks the spice of novelty and the tang of variety. The various things which typify engineering, which symbolize the profession the young man has elected to follow, are not a part of his educational environment. He is not permitted to handle engineering equipment, and there is no opportunity to send home to those who are vitally interested in sustaining his enthusiasm the personal snapshots of himself and new-found friends gathered about engineering things and materials. For this comparatively young student, all the thrill, all the enchantment, all the inspiration have been very effectually suppressed. As a result, in many cases there comes a reaction which may permanently affect the professional outlook and attitude of the individual. The bearing of the practical problems of curriculum building and problems of general educational administration are closed (and uninviting) volumes to engineering students and to many of those from whom he seeks advice. Our capable and devoted deans of freshmen and their advisers labor ineluctably and under the same handicaps as do parents who in desperation seek obedience through the phrase, "because I ask it of you."

The most effective teaching remedy in such situations is generally considered to be the device of substitution, and the very wide association of the slide rule with engineering activity suggests it as a desirable medium. The freshman has seen it in the hands of his engineering acquaintanceship, and he has marvelled at the ease with which an experienced person solves what appear to him to be involved problems. He will see it again in the hands of members of the faculty. He will see it, day by day, as a part of the working equipment of these outstanding and successful students whom he will come to respect and admire as composing the membership of the engineering honoraries. These associations naturally increase his desire to possess and use the instrument. I recall very distinctly discussing these matters and their bearing on teaching problems with one very good student. He was asked whether or not certain types of work would have meant more to him if they had been associated with the slide rule. He stated that one of the very first things he had done on coming to college was to obtain possession of a slide rule, and said in so many words that he felt that here was the badge of an engineer. His possession of it indicated to every one that he was trying to be an engineer. "All those whom I knew and respected as engineering students had them and used them, and mine made me feel a part of

their group." A quiet and confidential talk with your students will verify the fact that the slide rule has come to typify their profession, that the boys prize it and wish to possess it as one of the things which to them symbolize engineering, and that it will serve in a measure as a substitute for the things which have necessarily been taken away or the possession of which has to be deferred. It is highly important that any young man who has gone as far as this should be given something which signifies his acceptance, if only to the novitiate, and that this thing should be made a matter of pride with him, as much as his fraternity pledge pin or the seal of his university.

Examination of the usefulness of the instrument to an engineering student and its psychological value show plainly that here we have a problem which has all the elements of a real engineering teaching problem. There are additional advantages. It must be admitted, of course, that any fundamental operation which in itself is nothing more or less than a manipulative experience can hardly justify itself as a portion of the engineering curriculum, but, obviously, it will be found upon examination that the slide rule is not purely a manipulative process. Again, what might be considered purely manipulative drill work in the senior year may in the freshman year be of a highly valuable mental character. In a way, it may be compared to the use of a catalyst in chemistry. While not exactly a part of the mental operation itself, it induces mental correlations which are highly valuable. The extreme difficulty experienced in making mathematics real is common to all. When one begins to apply the principles of mensuration and to arrive at values through the medium of the slide rule, there is a very decided, revivified mental correlation by the student and a broader conception of the general nature of such operations on his part.

The student can be interested, of course, in the theory of logarithms in a new and attractive way. Checking back from the various scales to the scale of logarithms, he begins to get a geometric conception of the fact that the logarithm and the number bear a definite relation to each other. Manipulation makes concrete and tactual his mathematical conceptions of logarithms and through them the theory of exponents. If the student's acquaintanceship with the rule is not made purely mechanical, and if the teacher encourages the boy to study out original settings, if only for very simple formulæ, he thus learns to build up an orderly procedure for the purpose of solving mechanically certain problems. The analytical training received in this study very closely approximates the very high training value for engineering stu-

dents already known to be inherent in the study of descriptive geometry. For the freshman, such a teaching approach undoubtedly encourages initiative, resourcefulness, self-confidence, and self-esteem. Its study should help to develop judgment.

Required training and use of the slide rule involve very definite and explicit instruction to the student concerning the limitations of the instrument. Possessing as it does many great and obvious advantages for the engineering student, there are times when it is a liability, when its use would introduce an additional source of error, but early and continued training should cultivate the discretion of the student in a very definite way as to what is and what is not safe to use in engineering practice. Many of us are quite prone to say that in matters of accuracy the slide rule is always inferior to log book calculations. However, occasions sometimes arise in which, due to the nature of the problem, it is possible to obtain greater accuracy from a good slide rule than from the tables of logarithms usually found in the possession of the engineering student. As an illustration, consider the calculations used in curved beam formulæ (when determining stresses in crane hooks, piston rings, links, etc.). This involves the evaluation of the logarithm of $2R + d$ and $2R - d$, where $R$ is the radius of curvature and $d$ is the thickness of the beam. $2R + d$ and $2R - d$ can be found from ordinary Briggs tables, but the natural logarithms of their quotient cannot usually be so obtained with sufficient accuracy, while the log-log slide rule will yield the required number of decimal places.

Development of this line of thought will, of course, emphasize to the student a thing in which we are all very much interested, his judgment of the real meaning of the term, "significant figures," and the student will be encouraged not to render himself silly by the use of excessive accuracy. At the same time, he will be encouraged to know when such accuracy is required. In an attenuated sense, its use should serve to develop character by reason of the fact that discriminating and intelligent use will teach the student not to use inappropriate, but easy methods for the solution of problems whose proper prosecution requires tedious effort.

With the idea definitely in our minds that we have, first, a highly valuable psychological factor in the opinion of the student, second, educational material which is definitely prerequisite to a large portion of his future work, and third, in the present overcrowded state of our curriculum, a time-saver which will help in many of our time overhead problems, we come to a consideration of the place to teach and the method of teaching the slide rule.

The analysis of the desirable ends which may be attained in

connection with this work indicates that a considerable amount of time is not only necessary, but justifiable. This time may be used in small units, but should be continuous. By careful estimate, the minimum amount of time necessary for the instruction which freshmen require for a reasonable proficiency in the rule cannot be reduced much below thirty minutes per week. This time factor, of course, immediately proscribes any serious thought of introducing to present crowded curricula a new and separate course aimed particularly at the mastery of the instrument. Hence, instruction in the use of the rule must be in association with some present course, preferably early in the freshman year. In the teaching of any instrument in engineering, it may be stated with some assurance that progress in the handling of the instrument must be fairly rapid in order to retain interest and enthusiasm. Any other procedure would be sure to produce antagonism and ennui. Further, it may be stated that to secure a working mastery of the slide rule, the student must have continued practice, since, in the beginning, interruptions of even a short period of time tend to nullify the benefits of previous practice. Since practice, practice, practice is the absolute essential for final perfection, it must be assumed that the student will find some additional time and additional training by immediately applying what he knows about the slide rule to the solution of his freshman problems. If instruction is attempted in connection with subjects or topics involving difficult formulæ, which in themselves impose a heavy mental load upon the student, his attention will be distracted from the acquisition of proper technique, his answers in all probability will not be satisfactory to him, and he will be discouraged, not knowing whether his difficulty is with the rule or with the problem. Being human and proud of himself, the all too prevalent tendency is to blame and discard the rule in view of the fact that the student has a long and tedious, but mentally more easy way of solving the problem. This indicates that the teaching must be tied to some subject in which the calculation problems are of an elementary nature. While it seems absurd to set an engineering student to working out such problems as two times three equals six, I want to assure you that when such a problem is solved, and the student mechanically adds the log of two to the log of three and obtains six, he experiences a very genuine thrill.

By starting the student in on very elementary problems in multiplication and division and by encouraging and urging him to use the rule in connection with such subjects as freshman shops, freshman chemistry, etc., as a check on his logarithmic calculations, the general result is to give him a considerable amount of

additional practice time. When time is taken from any given subject and devoted to the slide rule, it should contribute very largely to an increased efficiency, as well as promote at least some of the major objectives. It is quite obvious that there must be no serious conflict in teaching ideals where such related material is presented. Hence, it is not logical to teach the use of the engineering slide rule in connection with the course in mathematics, where the objective is undoubtedly to imbue the student with a proper conception of exact mathematical accuracy, and where slide rule manipulation cannot be utilized to promote interest in the major objectives, since successful work with the slide rule involves large manipulative skill and the rise of acceptable approximations.

In the beginning use of the slide rule, manipulation presents a very real problem to the student. For good results, this requires personal contact between the student and the instructor during the period of instruction. Principles may be explained, demonstrations may be given, settings may be specified, but in the beginning it will be found necessary to stand beside each student and work out his personal difficulties, to check personally not only his answers, but his operation of the rule.

Considering the points presented above, indications definitely associate this instruction with the freshman engineering drawing course. Again referring to the psychological factor in our teaching, many of our readers will recall the form of the curve of learning for subjects which involve manipulative skills. The initial rapid rise, the early and continued flattening off of the learning curve to a plateau, and its subsequent drop are all too characteristic of the accomplishment of many students in engineering drawing. It is reasonable to say that for fifty per cent of our engineering students, the learning curve in drawing alone has already approached not only the beginning of the plateau, but is dropping and has degenerated into a curve of forgetting. It is unfortunately true that the important element of novelty is gone from engineering drawing for many of our first year students and that in a great many cases this vital element has been eliminated in the prosecution of a preparatory course whose mental content is far below the minimum requirement necessary for engineering students. On the basis of a study of this learning curve in engineering drawing, it seems reasonable to state that there need be no curve of forgetting, that there need be no plateau in the curve of learning for students. The mere fact that such a typical curve has been established does not mean that it should be accepted by drawing teachers. As teachers, we all appreciate the tremendous value of interest in a lesson or in a course, and if we definitely locate the

average points at which plateaus are apt to occur and make a studied effort to insert a new interest factor at such points, we should be able to keep our curve of learning rising instead of permitting it to drop back. It is quite true that there must be new interest factors, not once, but a dozen times and that the complete learning curve for a subject will be the influence of a series of learning curves, instead of one individual curve. The working out of interest material of this kind with engineering students unquestionably introduces a new and very vital interest factor for teachers of drawing perhaps inclined to become more or less educationally inert through repetition of elementary drawing problems.

Taking into consideration this need for a new interest factor in the study of engineering drawing and the points outlined above, drawing and the teaching of slide rule come logically into combination. The minute we introduce the slide rule in connection with our engineering drawing, we have it in a natural atmosphere. All the associations of this instrument in the minds of the students were made in situations in which drawing was undobubtedly present. When to the study of his engineering drawing he adds the necessity of considering it in detail for the purpose of making calculation, the drawing course takes on a new aspect. If the student is using his simplest three-view drawings of a rectangular prism for the purpose of calculating the volume, then the necessity for dimensioning becomes real. His study of the relation of a "plan view" as a "square" becomes a meaningful procedure. When figuring volumes, he is literally forced to travel from one view to the other and to realize the fact that one view is not enough to give him a definite idea of an object. Immediately, a natural association between the problems in mathematics and the problems in drawing begins to form. His visualization of the subject becomes definite and accurate. In a drawing course in which the slide rule practice is associated with the work in drawing, the instructor is no longer outwitted or outguessed by the students. Many of you recall our old procedure. We stepped to the side of the student, glanced over his work, and said, "Do you have a visual image of this drawing?" The student of course said, "Yes." The answer of necessity has to be not what the student visualizes, but what the instructor visualizes. When the student has worked out the volume with his slide rule, the instructor glances at the mathematical answer and knows definitely whether that student has visualized that object in detail. If in his study and analysis the student has missed any element in a well laid out drawing with related slide rule problem, the mathematical answer immediately indicates to the teacher what particular item the student has

neglected. If in addition to the mere calculation of the volume, the student is asked to calculate the weight in terms of different materials such as brass, bronze, etc., and is given the opportunity of comparing weights in different materials, there is in his thinking consideration of the properties of these materials, which is essentially a part of the engineering visualization of a solid. If we were to try to obtain these same benefits by mathematical longhand calculation, we would immediately inflict a tremendous overhead of antagonism on the drawing course. Engineering students undoubtedly need a review of the principles of mensuration. Undoubtedly the benefits to be obtained from the consideration of various types of surfaces, when taken in combination as representing typical solids, is highly desirable. Yet, the engineering college which would definitely insert in its curriculum a review of mensuration and arithmetic would undoubtedly come in for very serious criticism. When I say to you that in teaching drawing we discover that the students are not familiar with the real divisions of an inch, that in the lay-out of our beginning problems we must very carefully consider the fineness of fractions, I run the risk of being considered absurd. Yet, any honest drawing teacher will tell you that time and time again he finds it necessary to explain not only scale proportions, but also the scale of standard divisions, and that it is a real struggle to get the student to the point of a 100 per cent discrimination between the divisions on a triangular wood box scale. How much more chance, then, do we run of an insufficient, inaccurate, and totally unsatisfactory understanding of the meanings of surfaces and solids and volumes. It seems, therefore, that when we can gain all these desirable advantages by a correlated slide rule course, the neglect to do so might readily be criticized by thinking people.

If we can decide then that the teaching of the slide rule is not only desirable, but that its natural environment is in the engineering drawing department, we may proceed logically to the development of a program of related teaching. The development of such a program depends upon the nature of the drawing course.

Some very practical considerations are very soon apparent. In the first place, it is essential that the class be provided with a uniform type of instrument. While it is quite true that many of the instruments will produce the same results by a different series of settings, it must be remembered that at the beginning students are not capable of making these settings. An attempt to demonstrate the theory of a log-log trig by means of a model of the Polyphase Duplex can only result in confusion. It has been found to be essential that the instructor use the same rule for demonstration as

the students are using, and the uniform type of rule for the student group is prerequisite.

It must be remembered when choosing a slide rule for an engineering student who is to take a course in mechanical, civil, or electrical engineering that he is obligated to take minor courses in practically all of the other departments. That is a radically different proposition from choosing a slide rule which will satisfy the demands of a particular branch of engineering. Obviously, the decision for the sake of the student rests with that particular type of instrument which will satisfy all the exacting demands of all branches of engineering. From the financial standpoint, there is nothing that interferes with this decision since the range of prices is rather narrow. Yet, if we, as instructors, are endowed with a portion of the self-confidence that should be the background of every engineering personality, we will realize that this merely affords us an opportunity to sit down with the student and work out a common problem. The process cannot result in anything but a highly stimulating experience to the student, a tendency to bring him up to our own level by virtue of the feeling it creates that here is a thing which we both may learn together.

Since, as was pointed out a little while ago, the slide rule is as much the badge of the engineer as the cross is the badge of the Christian, then the rule which you suggest to your students should typify in the excellence of its every feature the very closest approach to engineering excellence which is obtainable. In choosing it, pick one which will make the prospective engineer proud of its possession. If possible, mark it so that it is not only indicative of his profession, but of his university as well. If these things involve a matter of slightly increased cost, I do not think that we need to be concerned. It has been stated above that you will find that the engineering student has ardently desired possession of this instrument. I think if you will investigate, you will find that many of them have bought rules inadvisedly, and rather than be embarrassed by something which does not represent their real ideal, they purchased a second rule. In the choice of this rule, you will consider also that the student is making, if the evidence in the preceding charts can be trusted, a continued use of the instrument, that it will be much more of a time-saving device than the typewriter which so many use, and that it will be with him as constantly as his drawing instruments. If we were to divide the cost of the rule by the number of hours of tedious and time-consuming toil he would spend in calculation without it, we would find that the cost per hour would be negligible. Beyond this, we must remember that he will go out into the engineering world, carrying

with him this symbol of his profession and reminder of his college days. When he goes into such an environment, the character of the instrument finally chosen speaks not only of the high quality of his preparation, but of the judgment of the institution from which he came.

In conclusion, if you should embark upon a program of teaching your engineering students the use of the slide rule, you must not expect to solve your difficulties at once, but you must look forward to a continually developing program, possibly temporary failure, even occasional uninterested students, but in the end I believe that you will agree with me that here we have found one of those fundamental things which add tremendously to the interest and enthusiasm so necessary to us older teachers who have a tendency towards routine and stagnation. You will have done one thing to cause your students to remember with gratitude your part in their engineering education.

# The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

*Convention Exhibits.*—By far the most outstanding features, from the standpoint of engineering drawing teachers, in a noteworthy convention were the exhibits of old books on drawing, descriptive geometry and related subjects; the collection of old drawings; the display of drawing tools, both ancient and modern, and the competitive student's drawings submitted in the annual competition in Engineering Drawing. Comments on the exhibits will be made in a later issue; space requirements limit this page to announcements of winners in the competition.

The judges of the competition, Professor Furman of Stevens, Professor Albert of Cornell, and Mr. John Boyd of Westinghouse, found the selection of winners and the placing of awards a difficult matter requiring considerable time and study. This not only indicates the high quality of the work submitted but also the relatively small differences in merit between entries.

The awards are as follows, both individuals and the institutions receiving suitable shingles designed by Professor Thomas E. French to commemorate the award:

Class *A:* "A pencil drawning made with instruments embodying an orthographic shape description only."

| *Institution* | *Student* | *Instructor* |
|---|---|---|
| 1. Northeastern University | Magoon, Herbert W. | Cleveland, L. F. |
| 2. Case School of App. Sci. | Kunz, P. Y. | Coppersmith, C. W. |
| 3. Union College | Male, M. J. | Schauffler, Henry |

Class *B:* "A pencil drawing made with instruments, including both an orthographic shape and size description."

| | | |
|---|---|---|
| 1. University of Wisconsin | Brooks, Clifford A. | Worseneroft, R. R. |
| 2. Virginia Polytechnic | Kerfoot, F. W. | Hill, C. C. |
| 3. Case School of App. Sci. | Szago, Carl | Nudd, W. E. |

Class *C:* "An inked drawing made with instruments . . . which shall include all the features of a working drawing."

| | | |
|---|---|---|
| 1. University of Nebraska | Parker, John | Aakhus, T. T. |
| 2. Oregon State Ag. College | Morris, R. O. | Wiley, E. C. |
| 3. University of Wisconsin | Parrott, F. W. | Griffith, F. O. |

Class *D:* "A freehand pictorial sketch."

| | | |
|---|---|---|
| 1. Lafayette College | Wolf, R. | Kennard, H. J. |
| 2. Northeastern University | Hatfield, A. C. | Cleveland, L. F. |
| 3. Texas A. & M. College | Ott, P. E. | Spencer, H. C. |

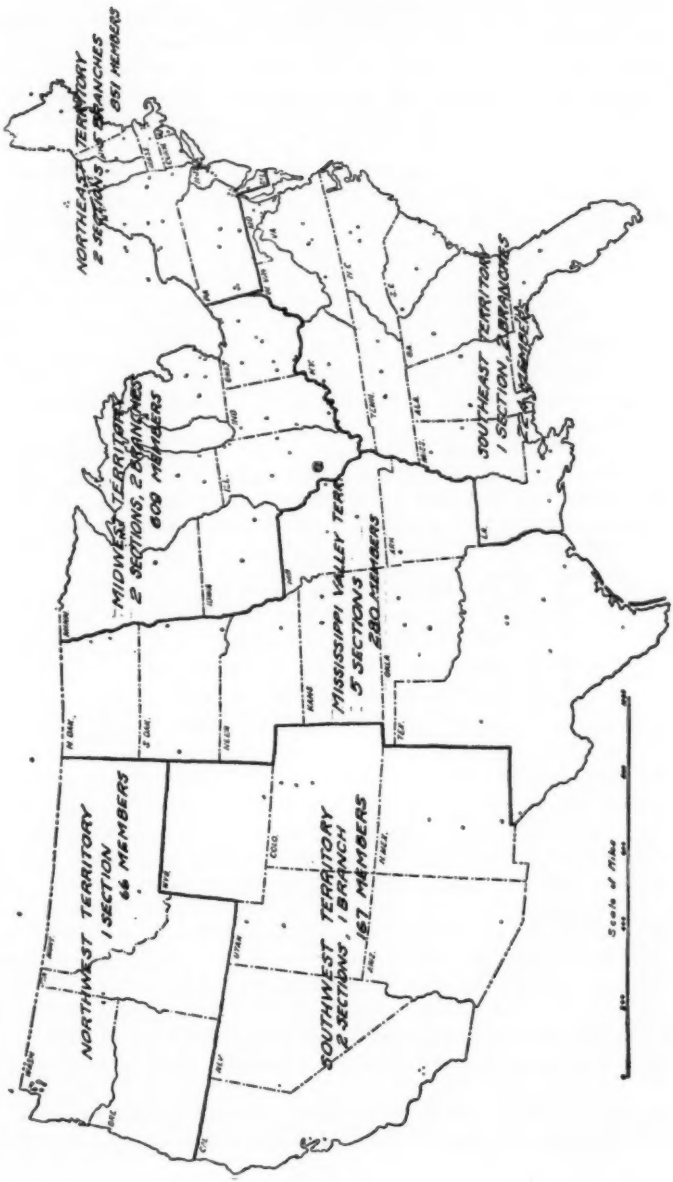
## REPORT OF THE COMMITTEE ON SECTIONS AND BRANCHES

Your Committee on Sections and Branches has interested itself in a study of what sections and branches we have, how active they are, and what membership they serve. The committee believes a "consummation devoutly to be wished" would be a section or branch available for every member who cares to attend. The Society has already encouraged these subdivisions to such an extent that the above consummation is not so very far from realization. A study of the section and branch meetings held during the past year shows that approximately fifty per cent of our members attend. Of course, attendance on some of these meetings sometimes entails a trip of nearly a thousand miles, but our great West is made up of men with real enthusiasm for the good cause.

| Territory | Members | Per Cent of Total | Sections | Branches | Reported Meetings | Attend. |
|---|---|---|---|---|---|---|
| Northeast | 851 | 38.8 | 2 | 5 | 8 | 425 |
| Southeast | 224 | 10.2 | 1 | 2 | 3 | 75 |
| Midwest | 609 | 27.7 | 2 | 2 | 9 | 245 |
| Mississippi Valley | 280 | 12.7 | 5 | — | 3 | 250 |
| Northwest | 66 | 3.0 | 1 | — | 1 | 75 |
| Southwest | 167 | 7.6 | 2 | 1 | 1 | 50 |
| Total | 2,197 | 100.0 | 13 | 10 | 25 | 1,120 |

Professor H. B. Langille, of the University of California, has been making a valuable study of the possible formation of an Arizona-New Mexico Section, since the colleges in those states are relatively far from the meetings of the Pacific Southwest Section to the west, the Texas Section to the east, or the Colorado-Wyoming Section to the north. The results of this investigation, which took the form of a questionnaire, so far are inconclusive. There are too few members involved and their allegiences too scattered to make any change at the present time.

Professor S. B. Folk, of Ohio State University, reports that a section is forming in Michigan, and that an organization meeting held last December was attended by 125 people. This group has not yet become a full fledged section, but will operate this year under an executive committee of nine members.


NORTHEAST TERRITORY
2 SECTIONS, 1 BRANCHES
851 MEMBERS
MIDWEST TERRITORY
2 SECTIONS, 2 BRANCHES
609 MEMBERS
MISSISSIPPI VALLEY TERR
5 SECTIONS
280 MEMBERS
SOUTHEAST TERRITORY
1 SECTION, 2 BRANCHES
NORTHWEST TERRITORY
1 SECTION
46 MEMBERS
SOUTHWEST TERRITORY
2 SECTIONS, 1 BRANCH
187 MEMBERS
Scale of Miles

Dean Floyd Field, of Georgia School of Technology, is working on the possibilities of forming additional subdivisions in the southeastern territory. This part of the country is perhaps the least organized of any, there being but one section (Kentucky) and two branches. It is a large territory with not too many members. A district meeting at Atlanta, planned for this fall, should determine the possibilities of forming sections and branches in the southeast.

The Middle Atlantic Section is the largest in numbers, but leaves practically untouched upper New York State and southeastern Canada. Some consideration has been given to the formation of a section in this part of the country, where there are 14 institutions and over a hundred members not affiliated with any existing section. Some of these institutions are favorable, but many feel that distances are too great, and life already too highly organized.

The committee is glad to report the organization of three new branches during the past six months. These are at Lafayette, Bucknell and University of Colorado.

Your committee has tried to point out some of the problems it has before it. It feels that the consideration of the formation of new sections and branches is its chief business, and that such new subdivisions will add new life and new members to the Society.

Respectfully submitted,

W. M. Cobleigh, Montana State College.
Floyd Field, Georgia School of Technology.
S. B. Folk, Ohio State University.
H. B. Langille, University of California.
I. H. Lovett, Missouri School of Mines.
C. G. Thatcher, Swarthmore College (*Chairman*).

## REPORT OF THE COMMITTEE ON RELATIONS WITH ENGINEERING SOCIETIES

Coöperation with the Engineering Societies during the past year has been exclusively concerned with the progress and development of the Engineers' Council for Professional Development. The Society has been represented on the Council by D. C. Jackson, H. P. Hammond, and R. I. Rees. The chairman of the E.C.P.D. will submit a complete report, so the report of your committee will be brief. The work of E.C.P.D. has devolved upon the Executive Committee and four other functioning committees. A brief report of each of these functioning committees is submitted.

### I. The Committee on Selection and Guidance

The instructions to this committee were to develop further means for the educational and vocational orientation of young men with respect to the responsibilities and opportunities of engineers.

First, the committee carefully considered all the guidance literature available and after due deliberation, a subcommittee consisting of O. J. Ferguson and W. B. Plank reported that "Engineering: A Career—A Culture" was the most suitable for the present purposes of the committee.

Second, the committee considered methods by which guidance agencies could be provided in the more important centers.

It was also deemed important that some measure of the effectiveness of the pamphlet "Engineering: A Career—A Culture" should be provided and tried out. This was done by preparing two sets of questions for use by a small group of engineering colleges who were asked to invite local high school juniors and seniors to a meeting. A set of questions was given each student at the beginning of the program to test his knowledge of engineering. He was then given a series of short talks and a copy of the pamphlet to read carefully. He then answered a second set of questions. One conclusion was clear. It is expressed by the comment, "I did not know the field of engineering was so broad"; therefore the pamphlet is helpful.

A second set of objective tests is being prepared and awaits expert opinion of their validity. Funds for this purpose are necessary.

When this double set of questions has been tested in a few institutions, it is the plan of the committee to request a large number

of engineering colleges to use the tests (*a*) to bring them in contact with promising local candidates, (*b*) to test the value of the pamphlet, and (*c*) to serve as a guide in the selection of students who would profit from pursuing an engineering curriculum.

Third, if the above procedure is promising, then an appeal will be made to local sections of the coöperating societies to set up a guidance bureau, committee or counselor to contact with the high schools, and to pursue such methods as the two may consider most effective. The pamphlet will be an important informative agent which may be supplemented by talks to interested groups and by individual conferences. The best technique to pursue will depend on the tact and interest of local section officers in presenting the subject to high school principals and superintendents.

The subject of guidance has been taken up with the Boy Scouts of America which is very willing to coöperate.

The National Occupational Conference has been consulted and is familiar with details of our proposed program.

There are many details to work out. The questions will serve the purpose of arousing interest and suggesting values in engineering training not suspected.

It is hoped that the proposed objective tests will be perfected during the summer and that an active program in guidance may be carried through next year. A permanent organization for this purpose is desirable and will depend for its effectiveness on the coöperation of the National Engineering Societies which form the E.C.P.D.

## II. The Committee on Engineering Schools

At a meeting of the committee held in Chicago in June 1933, a policy for the committee, a basis for accrediting engineering schools, and a tentative form of questionnaire were apporved in principle by the committee. In September, a formal report incorporating the method of approach and procedure of the committee in formulating its policy and laying down the basis for the accrediting program was approved by a majority of the committee and submitted to the Engineers' Council at its annual meeting in October. The following recommendations to the Council were approved by that body:

(*a*) That the E.C.P.D. undertake a program of accrediting the curricula of the various schools of engineering which are deserving of approval by the Council as representing sound and adequate instruction in particular fields of engineering.

(*b*) That the "Basis for accrediting engineering colleges" as appearing in Appendix B–1 of this report be approved by the

E.C.P.D. as representing the basic principles which should underlie such a program of accrediting.

The report and proposed program of the committee were submitted by the Council of the E.C.P.D. to the member societies and the program has been approved by the American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, and with certain reservations by the American Institute of Chemical Engineers. A committee of the American Institute of Electrical Engineers has the matter under consideration at the present time.

The proposed form of questionnaire was submitted to the members of the committee to be filled out for their respective institutions, in order to ascertain the suitability of this form for general use by the committee. A number of suggestions resulted from this move and in the light of these suggestions and certain others the questionnaire has gone through several revisions and now approaches a generally acceptable form.

The next important problem for consideration by the committee is that of the most suitable organization, policy, and procedure in carrying out the actual accrediting.

## III. The Committee on Professional Training

The last annual report of this committee defined objectives for the succeeding year and a brief report of progress is as follows:

1. A tentative survey of the junior membership of the constituent bodies of the Council has been made and a number of experimental investigations carried on. During the year it was decided not to adopt the questionnaire method of gaining information, but to attempt to work through local sections when portions of the plan are put into operation.

2. The Personal Appraisal Blank has gone through a large number of revisions during the past year and it is believed by the committee that it is now in final form and ready to go to press.

3. The committee has gathered together a considerable amount of literature concerning educational facilities in areas of concentration of junior membership and is now quite well prepared to give definite information along these lines. One encouraging general development during the past year has been the organization of city and community councils on adult education. Each council has assembled detailed information on leisure time opportunities for formal study.

4. Much time has been devoted by numbers of people in a constant revision of the Reading List for Junior Engineers. It has undergone a number of revisions during the past year and while

it will never be satisfactory to the members of the committee, it has met with their final approval and this list is ready for the press.

5. The committee on professional training realizes that its most serious problem for the coming year will be to set up a program of education and training which will meet the criteria of achievement described by the committee on professional recognition. It is still awaiting determination by the latter committee.

6. The question of the manner in which the work of this committee should operate is still open. As far as the committee is concerned, and in keeping with the controls of the work of the Council by its constituent bodies, it now seems advisable to turn over the material to the respective organizations and have them carry on the work in an effective way through divisions, local sections, and student branches, in a manner best adapted to the organization and traditions of each society.

## IV. The Committee on Professional Recognition

Last October E.C.P.D. approved the recommendations of the Committee on Professional Recognition that the minimum definition of the engineer and the standard grades of membership be recommended to the participating bodies by asking each participating body to appoint two representatives to a conference group to discuss the matter. This conference group was held on April 10th and it was the unanimous action of that group that the recommendations be approved and forwarded to the participating bodies for formal consideration. These recommendations are being forwarded at the present time and it is hoped that they will reach the participating bodies in time for official action during the various meetings held in May and June.

## V. Ways and Means Committee

Engineering Foundation has granted $2,800 for the following four projects:

Selection and Guidance,
Professional Training,
Professional Recognition,
Publications.

The Executive Committee of Engineering Foundation has not been able to meet to discuss the question of accrediting schools, so a letter ballot was sent out to the members of the Executive Committee on June 15, 1934, with a strong recommendation from the

Director of Engineering Foundation that $3,800 be appropriated for the accrediting schools project.

Respectfully submitted,

R. I. REES, *Chairman,*
D. C. JACKSON,
A. H. WHITE,
A. H. FULLER,
W. B. PLANK,
F. L. BISHOP.

*Note:* This has, unfortunately, been a report by the chairman, as it was impossible for him to arrange a meeting of the committee prior to the rendition of this report.

# FINAL REPORT OF THE CHAIRMAN OF THE BOARD OF INVESTIGATION AND COÖRDINATION *

## A BRIEF: SUMMARIZING THE RESULTS OF THE INVESTIGATION OF ENGINEERING EDUCATION AND RELATED ACTIVITIES

CHARLES F. SCOTT

> "It is therefore proposed that the investigation of the Society be directed to a study of the objects of Engineering Education and the fitness of the present day curriculum for preparing the student for his profession." (From Memorandum, May 1923.) 10†

### FOREWORD

The Investigation was initiated in 1922 by approval of the Council of the Society for the Promotion of Engineering Education of the recommendation of a Development Committee that a Board of Investigation and Coördination direct a new project of the Society, "to develop, broaden and enrich Engineering Education." The name of the Board indicated more than mere investigation of facts and conditions; it looked forward to greater unity in the activities of the engineering colleges; it also implied leadership in "Coördination" for concerted effort by the schools to improve the quality of their work and to mesh in with the changing needs of practice.

At its annual convention, June, 1923, the Society pledged active participation; a letter from Dr. Pritchett was read giving assurance of Carnegie Funds which were formally granted in October, and W. E. Wickenden was chosen as Director of Investigations.

The Board of five was augmented by the President and the Secretary of the Society and by two non-engineering educators, President Aydelotte and Dean Seashore. An account of the inception of the project, the organization and procedure, and the fields covered will be found in the Report of the Chairman at the beginning of Volume I, the Preface to Volume II, and at the conclusion of this Foreword. Preliminary records are listed in the Bibliography.

*Definite activities* began late in 1923. Counsellors were appointed by the professional societies. Professor H. P. Hammond was made Associate Director in charge of relations with engineer-

* Presented at the Annual Convention of the Society, June 1934. Revised.
† References are to pages in bound Volumes I and II of the Report.

ing colleges. Various studies were undertaken under sponsorship of six committees of the Society. Faculty committees in 150 engineering colleges aided in securing data and in transmitting reports to the faculties. Data on personnel, students, graduates and teachers, on curricula, and costs and on other matters accompanied by reports of the committees were the basis of conclusions and recommendations in reports by Staff and Board.

*Publication.*—Reports on various projects were continuously published and issued to the Society through its monthly JOURNAL OF ENGINEERING EDUCATION. Reprints in pamphlets and a series of Bulletins together with a Summary of the Fact-Gathering Stages of the Investigation were issued in 1926. Later on a score of these were revised and assembled together with Director Wickenden's "Comparative Study of Engineering Education in the United States and in Europe," in Volume I of the general Report which was issued in 1930; the remainder of the record now appears as Volume II, which contains a comprehensive index.

*Summer Schools for Engineering Teachers* proposed by the Staff, and supported by the Carnegie Corporation and others were inaugurated in 1927 by three-weeks sessions at Cornell University and the University of Wisconsin. The sessions continued through the summer of 1933, and covered the important subjects of the curriculum.

*The 1930 Survey*, supplementing the general investigation, was made by means of a questionnaire issued in coöperation with the United States Office of Education, affords data of the engineering colleges intended primarily for comparison with the conditions five years earlier.

*A Conference of Administrative Officers* of Engineering Colleges, held in 1933, dealt with administrative as distinguished from educational problems of engineering colleges. Topics considered were: status of Engineering Colleges in 1933, the outlook, budgeting, development of teachers, students' personnel problems, graduate work, Junior Colleges, engineering education in the light of changed social and economic conditions, external relationships, accrediting of engineering colleges.[1145]

*A Study of Technical Institutes* (non-collegiate) made in 1928–29 was conducted by Director Wickenden and special staff (B. H. Spahr, principal member) with counsel of an Advisory Committee. It throws light on a related type of technological education.

The foregoing outlines the expanding program sponsored by the Board, created in 1922, dissolved in 1934. Supplementing Carnegie Funds there were contributions by Engineering Societies, industries, educational institutions and individuals.

*Results and Conclusions* are now to be presented. In epitomizing some 1500 pages, including several hundred tables and charts, in less space than required for the tables of contents the stacatto summaries necessarily omit many items and many modifying conditions; these snap-shots may be amplified and brought to clearer focus by referring to the text.

While this report purports to be a Brief, summarizing the results of the investigation, it is frankly somewhat personal in that emphasis is laid on features appealing to the writer as most significant. He has not refrained from advancing his own views and opinions, particularly in the concluding section.

### *The Beginning of the Project*

The beginning of the project was as follows: The Nominating Committee in 1921, while overcoming my reluctance to accept the presidency of the Society, said that new activities were needed and pledged support. My first pastoral letter as President urged local groups to discuss methods of teaching. Something larger was needed but what? and how? The situation seemed intangible.

A leading dean remarked that he disliked investigations by outsiders. I concluded that we should work from within. I consulted President Angell, recently come to Yale. I said I was becoming obsessed with the significance of engineering in modern life; neither the profession and industry nor the schools themselves were satisfied with engineering education as it is, that clearer objectives and new methods were essential and that 150 schools needed coördination and leadership. Was I on the right track? He replied, as I recall, "Yes, engineering education does need something and it can probably best come from within. You will have more difficulty in finding your man than in getting your money, but first of all have you got the schools back of you?" And so I dropped my plan for getting money and asked the Society in the *Bulletin*, January, 1922, whether it would take up its own problems or wait outside compulsion. I continued my appeal and at the June convention a development committee was appointed which outlined a comprehensive program under a board of peculiar title. (The Report is printed in the Appendix.)

We soon began our quest for funds. During six months' negotiations with several foundations, we were impressed by the searching and discriminating inquiries which preceded the granting of funds. But we were successful. While we were searching for a director it happened that Mr. Wickenden showed me several charts summing up a comprehensive educational survey of the personnel of the Bell Telephone System. They showed abilities and

methods which our director should have. But would he measure up to the whole situation? I did not know him well, so I decided on a test. I asked him to present the results to the Society at its coming convention. Two months later his fascinating presentation of the charts produced a spell-bound interest which one could sense in the darkened room. Several immediately asked why not Wickenden for director? The Board elected him at once. After several months he decided to leave an outstanding position in industrial education with an expanding future for our adventure into the unknown with definite assurance of one year's financial support and two more if the first showed progress.

At last our plan for development was worked out, the schools pledged active participation, funds were forthcoming, and a director had been found—these preliminaries consumed two years.

These early plans had the benefit of Secretary Bishop's experience and balanced judgment.

From these beginnings, an able Board, a competent staff, earnest workers in the schools, and loyal supporters elsewhere produced the results which are here recorded.

## I. Personnel

"A discriminating study of the present state of Engineering Education" naturally began with a study of personnel—students, graduates, teachers. But for the facts one must go to a hundred and fifty independent institutions, with their thousands of teachers, tens of thousands of students and hundreds of thousands of graduates. Often there is diversity rather than conformity to type. Many questions must be answered by individuals as a first step to group averages.

The investigation set about to get the composite pictures of personnel by a fair sampling—securing data from many individuals.

*Sources of Data.*—Facts and opinions were secured concerning the following individuals in reply to questionnaires. In general, each individual contributed several and in many cases several scores of specific items of information or opinions—

| | | |
|---|---|---|
| Entering students | | 4,079 |
| Students (data furnished by institutions) | | 5,338 |
| Graduates, recent | 3,933 | |
| Graduates, older | 2,336 | |
| Graduates, Eta Kappa Nu | 844 | |
| Former Students | 721 | 7,834 |
| Teachers | | 2,289 |
| Engineers | | 1,058 |
| | | 20,598 |

The items of information thus secured run into the hundreds of thousands.

The foregoing does not include the totals of certain groups; *e.g.*, the 102,900 entrants which resulted in 41,547 graduates,[201] or the 8,598 teachers who are classified as to degrees held. It does not consider some 16,000 men in industry who are grouped as to educational courses and positions,[1019] nor the graduates of technical institutes, nor does it include the 1930 survey.

### *Entering Students*

Data from 4,000 (20% of the Engineering freshmen in the fall of 1924) show a median age just under 19 years; 96% were American born;[162] Business of fathers—29% industrial, 22% financial and mercantile, 17% farming and 16% professional.[163]

Positions of fathers—43% owner or proprietor, 28% executive and supervisory, 19% workmen, clerks, etc., 4%engineers, 2% teachers.[164]

Education of students' fathers—6% professional degree, 7% college degree, 11% non-graduate of college, 16% high school graduates, 15% non-graduate of high school, 27% graduate of grammar school, 15% less than grammar school.[165] In other words 45% did not enter high school and 76% did not enter college.

The homes of half the students are less than 107 miles from the school; but a considerable number draw half their students from less than 25 miles, 15% migrate from other states.[165]

Of the freshmen 90% had previously earned money; many a substantial amount during the previous year.[166]

Over 60% are from the honor group or the upper third of their classes in the high schools (and less than 3% from the lower third);[166] seven-eighths are from high schools, one-eighth from private preparatory schools or colleges. The quality of preparatory school education, however, is generally inferior as a foundation for an engineering course.[168]

The basis upon which students make their educational choice is wanting in an understanding of what engineering is and the type of man suited to an engineering career. Choice of engineering is made by half of engineering freshmen before entering the last year of high school.[170] While engineering freshmen are of high quality, as high school graduates many are not adapted to engineering careers.[170]

*Conclusions of the Committee.*—Assistance to high school students in gaining a perspective of engineering as a career, may be rendered by conferences, addresses, literature and moving pictures.[172]

Greater discrimination in admission methods is advised.

Orientation courses in early college years are recommended.[180, 183]

*The Report of the Board* holds that it is a duty of engineering colleges to the profession to attract and admit qualified students, and to reject the undesirable and unfit.[94]

The foregoing conclusions are re-affirmed and a joint agency for coöperation with secondary schools is recommended.[96] Selective admission procedure and subsequent tests are advised.[96]

### *Admission of Students*

Of 111 institutions 92% have paper requirements of 15 units, the others varying from 14 to 16.[196] Credentials from accredited high schools are accepted by 94%.[197] "Conditioned Students" numbered 20% of the admissions in 1924. Of 65 schools 20% use intelligence tests and 23% personal interviews, though not as part of the admission requirements.[199]

*Comments of the Committee.*—Entrance requirements have changed but little in 25 years,[198] and are, in general, about as high "as the traffic will bear." The fundamental problem is to secure better grounding in subjects taught and guidance in selection of electives in the high school.[200]

Should selective methods supplement scholastic credits? [200]

### *Elimination of Students*

Of over 5,300 freshmen in 25 institutions 40% did not survive to enter the sophomore year; similarly 30% of the sophomores and 25% of the juniors were eliminated and 16% of the seniors did not graduate; *i.e.*, only 28% of the entering freshmen graduated in 4 years.[202] Of the freshmen entering in 1899 to 1913 the number graduating four years later is 42%; this includes additions to the class by five-year men and transfers. This changes to 38% for the classes entering in 1914 to 1920. The 1930 survey shows that for three recent classes the corresponding figure is 40%. This survey shows also that 28% of the entering freshmen graduate four years later; this agrees with the findings of the earlier report. Canada, New England and the Middle Atlantic States show elimination ratio much less than the average.[200]

*Causes* are various. In 23 institutions (1923–24) causes were: Scholastic failure 54%; change of course 15%; financial 9%.[202] Causes assigned by institutions are, lack of ability or of interest 51%, poor preparation 16%; self-support 8%, fraternities and social activities 6%.[204]

*Committee Comment.*—Elimination (as well as admission) is not merely a matter of "clerical" arithmetic as the problems involved are vital and complex—not routine but personal. Factors in the situation are home training, preparatory education including subjects, objectives and quality as a basis for an engineering

education; aptitude and attitude of the student; diverting influences, social and athletic; lack of flexibility and stimulus in initial contacts and instruction; the purpose and character of the engineering school; the relation between the collegiate and the professional aspects of the under-graduate engineering school; the supplying of adequate recruits to the profession; the obligations of tax-supported institutions.

Truly the problem is complex. It has no simple answer, but it must first be stated and understood. One agency in solution is the skill of the teacher in aiding the student to overcome his difficulties and realize his ambitions.[207-214].

### *Graduates*

After admissions and eliminations come graduates. What of their careers? They themselves have supplied data and opinions.

Over 6,000 graduates from over 40 institutions (two thirds of whom graduated within 3 years) are in occupations closely identified with their college courses as follows, Civil Engineers 73.5%; Chemical Engineers 61%; others intermediate. There is more divergence among older graduates.[231]

Of recent graduates 70% are primarily technical in occupation, while 70% of older graduates are primarily administrative.[232]

Median earnings, as ascertained in 1924, increase from $1,500 to $7,500 at the end of 30 years; at that time 25% earn less than $4,300 and 25% more than $15,000.[233]

*Initial Positions* are secured through college or employer by 45%, through family or alumni connections by 17%; through work prior to graduation by 16%; through personal initiative by 14%.[235]

Reasons for choice of first position: definite field of college course 50%, good opportunities 26%, only one available 10%, desired locality 9%.[216]

One position had been held by 43% of the class of 1922 at the end of two and a half years; two positions by 32% and three or more by 25%.[236]

*Opinions of College Courses.*—Technical and scientific preparation and the relation of studies to problems and procedures of practice are rated good or excellent by 75% of graduates.[238]

Knowledge of fundamental principles of science and methods of thinking and habits of work are rated as of great or very great value in their college experience by 70%.[239]

Accuracy and thoroughness are developed by engineering courses to a high degree in the estimation of 80%; diligence, also integrity and dependability are similarly rated by 40%; initiative and originality by 37%, and qualities of leadership by 20%.[240]

As important omissions commercial and business subjects are cited by 51%, English by 26%, cultural subjects by 8%.[242]

*Continued study* is required by the positions of 75% of recent graduates; 51% have studied along the lines of their college courses and 27% along other lines; over 25% studied under supervision of employers; over 40% pursued cultural subjects.

Among cultural interests of graduates, Economics and Literature take leading places, followed by History, Psychology and Philosophy.[245]

*Conclusions of Committee.*—Two items are given emphasis. The need of guidance in the choice of first positions. Means suggested are lectures to seniors outlining various fields; more effective presentation by representatives of industry; personal records of students by colleges.[250]

Continuation of education after leaving college is essential to the graduate; it should be a responsibility of the colleges. Methods proposed are reading courses, correspondence courses, extension courses of various types, advisory services.[252–255]

### *The Engineering Graduate in Industry*

The National Industrial Conference Board Studies (1924–25) made under direction of a joint committee of industrialists and members of the S. P. E. E., supervised by A. C. Jewett are summarized by him in statistical tables and in comments.[1016]

The studies included six industries. The ratios of the employees in the companies coöperating in this survey to the total in the respective industries are: paper and pulp 32%, rubber 80%, textiles 30%, metal trades 14%, chemical 10%, and electrical 95%. In 1081 establishments over ten percent of the 581,000 employees hold executive or other positions of importance, in the first three industries above named the ratio is 7%, in the others 15%. Of these over one-fifth (13,000) are technically trained college men as follows: textile 10%, metal trades 12%, rubber 14%, paper and pulp 18%, chemical 24%, and electrical 33%. The major college subjects of technical and other college men were; electrical 40%, mechanical 20%, chemical 14%, other engineering 8%, non-engineering 18%.

The higher the industrial position the larger the proportion of college men. The proportion in production is low; 70% of the technical graduates are in sales and engineering, the greater number in the latter.

Of 3,800 general officers 30% are technical graduates and 20% are other college men; of 10,800 engineering and technical men the respective numbers are 46.5% and 2%; of 21,000 in production only 7% and 1%; of 15,000 in sales 30% and 8%; of 13,000 in

miscellaneous positions 9% and 4%; in a grand total of 64,000, 21% are technical and 4.4% are other college men.

These industries as a whole offer very meager training for graduates, only 31 (less than 3%) reporting organized systems. But as it is the larger companies which provide training the proportion of men receiving training is much greater than 3%.

Lack of specific knowledge (such as the industries might give in educational programs) rather than faulty school training is regarded as impediments to individual progress.

Summer work for college students is recommended by the graduates although few companies extend opportunities.

Graduates in general are satisfied with their technical preparation when their industrial work follows their major subjects; all do further studying.

Very few companies, other than large companies in the electrical and chemical industries, have systematic methods of recruitment. Representatives from a few companies give lectures at the colleges on various aspects of industry.

*Conclusions* based on statements of graduates and employers are that deficiencies in training are not limited to the engineering college but involve secondary schools (whose graduates are poorly educated and not properly directed) and the educational system as a whole, that the endeavors of leaders in industry and in education should be (*a*) in industry to aid in industrial guidance and in shortening the time for fitting graduates for responsible positions, and (*b*) in the colleges to develop personality, to give facility in expressing ideas in clear convincing English and to aid students in choice of positions adapted to their personality and training. The problem calls for coöperative attack.[1029]

### *Teaching Staffs*

Data were furnished by 2,300 teachers and over 100 institutions.

*Sources of Teachers.*—From same institution 38% (two fifths directly from graduating class); from other institutions 29% (one fourth from graduating class); from practice 28%. Annual loss; 10% (one third to other educational institutions).[275]

*Academic Salaries* (median) (1924) are initial, $1,500; in 20 years, $3,500; in 40 years, $4,700. Corresponding supplemental incomes (median) are, $300, $1,000, $1,800.[316, chart] Median academic salaries are slightly less than the earnings of three-quarters of the graduates.[278] The total income of teachers at the 30 year period is 75% of the earnings of graduates (median).[278] Median supplementary incomes are about 50% greater in industrial than in non-industrial centers.[286]

*The degrees* held by teachers of engineering subjects exceed the

number of teachers by 17% (3,693 degrees, 3,159 teachers) while the excess is 50% for teachers of chemistry and chemical engineering, economics and business, and 30% for teachers of sciences, mathematics, English and modern languages.[284]

*Professional practice* by teachers is permitted in all but 5 of 116 institutions. In these it is encouraged in more than two-thirds and discouraged in very few.[285]

*Opportunities for Development* are listed with comments under three heads.

(*a*) Sabbatical leave was taken by an average of 15 teachers per year from 116 institutions, and from among a total of some 3,000 teachers.[301]

(*b*) Assistance to younger teachers in securing summer employment is given by 70% of the institutions.[302]

(*c*) Instruction in the art of teaching is given in some or all departments by 10% of the schools and there is no systematic instruction in 85% (5% of 116 institutions did not reply). In a fifth of the schools older teachers visit the classes of younger teachers and in a third young teachers visit classes of experienced teachers. Three-fourths of the faculties indicate that instruction in methods is desirable but express much doubt as to whether a practical method could be found which would make it worthwhile.[289]

*Conclusions of Committee.* The situation is quite satisfactory insofar as can be judged by the statistics. But intangibles enter the educational problem.[289]

In the selection of teachers, administrative officers feel that recruits are not secured from the highest levels of graduates. Adequate salaries, opportunities for engineering practice and for research and scrutiny of all-round qualifications are remedial measures.[289-304]

The securing of the right type of teachers is a major problem in engineering education.[304, 1151]

## II. Curricula

Curricula—the *table d'hote* schedules of intellectual food arranged for students are offered in great variety and profusion, although each aims to afford a balanced ration of carbo-hydrates and proteins and vitamines.

*Requirements for Graduation* vary widely even in the major and fundamental subjects. In civil engineering, the patriarch which should logically be the most stabilized, the total credit hours range from 125 to 191.1 (a ratio of 2:3) in the 83 institutions listed. The total civil engineering subjects have credit hours ranging from 24 to 78 (1:3) while the non-engineering subjects vary from 39.4 to 102 (1:2.6). Comparable or greater variations are found in the other four principal branches of engineering.

Apparently the only common dimension is a length of four years.[454]

Fortunately vigorous youth has powers of selection and assimilation such that physical and intellectual development are not wholly determined by boarding house menus and curricula.[1068]

These variations in curricula are actually less astounding than they seem in view of the foregoing quoted range from maxima to minima. Curricula in a particular branch, *e.g.*, civil engineering, follow the customary pattern pretty closely in a majority of institutions. They exhibit a range, however, from a broad general education with scientific and engineering background at one extreme to specialized vocational training at the other. This topic is considered later on.

### *Evolutionary Trends*

Evolutionary trends in engineering curricula are traced in 10 typical institutions by comparisons made at 15-year periods from 1870 to 1915 and in 1923. The average for the several institutions shows that in each of the five major branches there is more time than formerly devoted to the major subject and less to foreign languages, shop and drawing. The composite of all courses in all institutions shows also a slight increase in engineering subjects other than those in the major field, in mechanics and hydraulics and in electives. There is a decrease in shop requirements after its peak in 1885. Among the general academic subjects there has been an increase since 1885 in physical sciences, in English and in economics and a slight decrease in mathematics. History decreased after 1885 and has recently held constant, though least in amount among the items listed. The subjects special to engineering occupy (1923) 2.4 and other subjects 1.6 of the 4 years. (These comparisons take no account of changes in entrance requirements or in the total credits for graduation.) [522] In 1870 there were 21 engineering schools, an increase of 15 in the preceding four years. At that time technical education with "its scientific basis and utilitarian aims was regarded as on a far lower plane than classical education." [543] Engineering courses were scientific rather than technical.[545] The evolution has been far more in quality of content than in the quantitative classification of subjects above noted. Changes in curricula have been the resultant of progressive scientific and technical knowledge, and of the changing demands in industrial and other fields which utilize men of engineering training.

### *Aim of Curricula*

Existing curricula aim to supply a grounding in scientific principles and the methods of engineering together with the elements of liberal culture. They do not afford a complete professional

training. They bring material from many fields to a common focus in technical activity. The present trend is placing greater emphasis on general rather than technical educational values. Specialized training follows graduation. Success as an educational process is attested by the many fields in which graduates have been successful.[554, 1070]

*Opinions regarding Curricula.*—Opinions from 534 experienced teachers in 115 institutions, 6269 graduates and 855 prominent members of engineering societies are presented in statistics and charts and are then epitomized as favoring the following:[413]

1. Moderate diversity, of curricula, but tending away from specialization;
2. Dominance of scientific and broadly technical content;
3. Inclusion of a well-identified core of required subject matter in common;
4. Inclusion at all stages of subjects of purely cultural value;
5. Due emphasis (though not predominant) on the economic aspects of engineering and on its concern with administration and management;
6. Coherence of arrangement and coördination of related subjects;
7. Thoroughness rather than completeness of detail.

## III. Graduate Work

Graduate courses were offered in 1924–25 by 81 institutions. Classified enrollments of 746 were reported by 49 institutions and unclassified of 256 by 28 institutions, a total enrollment of 1002. A single institution had 20% of the enrollment, 10 institutions had 87% of the enrollment.[322]

The number of advanced degrees for resident work granted in 1925 by 60 institutions was 572; of these 212 were Master of Science; 194 M.S. with Designation; 25 M.S. in Engineering; 78 included the word Engineer; 63 others included 11 different degrees, 8 of which were the grade of Doctor.[323]

*The Committee* remarks that nearly all of the degrees are for a single year in residence, that the work is largely of the undergraduate type; that really advanced instruction is given by very few institutions and that very few have faculties competent to train men for high-grade engineering research.[323]

*The Board* advocates graduate work in a few institutions with notable teachers; that this work be open only to proficient students; that additional undergraduate studies should not be considered as graduate work.[117, 123, 146]

## IV. The Coöperative Plan and Other Studies

The method of alternating attendance at school and at work in industry initiated by Dean Schneider at the University of Cincinnati in 1906 was adopted by five other schools in a decade and extended by 1925 to include approximately 10% of the engineering colleges, including leading institutions, and 10% of all engineering students of the country. The 16 schools covered by the report include municipal, endowed, sectarian and state supported institutions.[559]

*Periods of Alternation* between college and industry are of two kinds; either short, 4 weeks or less, or long, sometimes corresponding to the term or semester. A chart indicating the periods for 16 institutions shows that no two are alike.

*Coördination* between the work in school and that in industry is important and is commonly handled by a "Coördinator," usually an engineering graduate who has himself had coöperative training with supplemented industrial experience. He plans programs and is counsellor to the students.[559]

*Earnings* of coöperative students (1926) during the work period vary from a minimum of $15 a week during the first year to $50 in the fifth year. These rates vary materially in different parts of the country.[582]

*Results of Coöperative Plan.* Numerous comparisons between coöperative and other engineering graduates as to positions, earnings and general progress do not show marked differences. It is concluded that both methods produce equally meritorious results though not of identical character. Decision as to relative scholastic merits must await further experience and evidence.

The Coöperative Plan tends to early development of stamina, resourcefulness and sense of responsibility. It also acquaints the student with the importance of the human element in practical affairs. It supplies vocational guidance by the trial method. It facilitates the entrance of the graduate into industry. The cooperative plan affords a close link between the community and the college, a factor of mutual benefit.

*Summary.* In the broad field of technical training there is room for many types. The coöperative system has established its place and is particularly fitted for the training of men for production in manufacturing industries. Important factors in all education are the interest and enthusiasm of students and instructors—elements to which the success of the coöperative system is largely due when students are carefully selected and effective teachers are found.

### *Economics*

Four-fifths of the engineering colleges have a required course in economics. The subject matter covers the whole field of business

administration, finance, and accounting. Total hours in economics range from less than 25 to more than 150. Instruction, except in very few cases, is given outside the engineering departments. The major purpose of the course in two thirds of the colleges is instruction in broad economic theory while an additional 14% combine theory with specific problems. In most cases the teacher holds the rank of assistant professor or higher. Many colleges report that specific economic problems are introduced in their engineering instruction. The importance of economics is generally recognized and many colleges offer electives.[1031]

Replies were received from 127 mature engineers representing the various fields of engineering and occupying a variety of prominent positions. They report a wide range of topics in the general field of economics which they have encountered in their work, viz., valuations, price tendencies, labor problems, cost of public utility services, rates, transportation engineering, legislation, taxation, manufacturing, water power and works, salaries, personnel, business law, city planning, municipal engineering, traffic estimates, finance.

Questions of "Engineering Economics," such as the choice of the more economical method when two are available, the setting of operating charges against fixed costs, cost analysis, public utility problems, financing of industry, marketing and personnel problems, were found to be involved in one phase or another in the experience of practically all the engineers. The large majority advise the inclusion of both theoretical and practical economics in the engineering course. As to whether presentation should be thorough in character or general with emphasis on the importance of the problems involved opinions differed. Those who have had opportunity to observe the handling of economic problems by graduates of business courses and graduates of engineering courses report that the latter are much more competent.

*The Committee* in conclusion points out that the engineer who does not expect to remain "a hewer of wood and drawer of water" but to take a place as a leader in modern industry and business must be qualified to meet economic problems; that the engineering curriculum must confine itself to presentation of the fundamentals excluding topics that are not immediately essential. In what department and by what method and by what type of teachers economics should be presented are vital questions before the engineering colleges.[1038]

*The Board* stresses two objectives of the social and economic content of the curricula; an understanding of social institutions and the interplay of social forces, also the capacity to deal with specific economic problems arising in the realm of engineering.

The later is essentially technical and is a responsibility of engineering education. Economics is placed in the curriculum on a plane with mathematics and physical sciences.[90, 1058, 1156]

*Placement Examinations*

Placement Examinations—a series of educational tests designed to measure the training and aptitude of students for subjects commonly included in the first year of engineering curricula—a method employed at the University of Iowa—were introduced experimentally in a number of engineering colleges in the years 1924–25 and 1925–26. Many tests are recorded and from them conclusions are drawn.[689]

*Conclusions* drawn by the committee are as follows:[725]

A very great range in aptitude and preparation of entering students is demonstrated.

There is a considerable difference between the median scores of students in different institutions.

Placement examinations are valid instruments for predicting scholastic achievement.

They enable classes to be sectioned on the basis of ability for which the evidence cited is generally favorable; sectioning enables classification on basis of preparation as well as ability.

Placement examinations are ineffective in themselves. They furnish the data upon which remedial measures may be based, however, and when administered systematically and discriminatingly they may be of considerable importance in dealing with students.

*Research*

Organized engineering research was conducted (1924–25) by 64 engineering colleges in the United States and Canada. An itemized list of particulars shows that there were in progress in June, 1925, 568 projects; that the number of publications issued to that date was 1,658; that the research staff consisted of 927 persons of all grades and that the annual research funds were $1,401,264.

The above figures do not include certain institutions among them Harvard, Yale, Princeton, Columbia and Pennsylvania where research is conducted but not under the type of organization included in the foregoing report. Furthermore the tabular data have various limitations so that the figures given must be regarded simply as indicating general values.

Only 29 institutions report expenditures of $5,000; 75% of the expenditure is by 10 institutions and 90% by 22.

*The Committee* points out that the "Research" in many in-

stitutions is routine testing rather than scientific investigation; that true research is limited to but few institutions; that the total expenditure is only 5% of that for under-graduate instruction; that this amount is exceeded by at least 4 industrial concerns in their research activities; that the importance of research both for its immediate results and for the training of men for research justifies increased development and expenditures.[320]

### *The Costs of Engineering Education*

Data on costs were supplied by 45 institutions of various types having 21,190 students, graduating 3,035 in June, 1925 (the year for which the financial data were given), show the following sources and distribution of funds.[341]

Sources from which funds to meet cost per engineering student per year are obtained (cost including interest on plant $610, excluding interest $487).[355]

| | | |
|---|---|---|
| Paid by student | $172.00 | 28.2% |
| From endowment | 124.00 | 20.4% |
| Interest on plant | 123.00 | 20.2% |
| Public appropriation | 142.00 | 23.2% |
| Other sources | 49.00 | 8.0% |
| Total | $610.00 | 100.0% |

Distribution of expenditures for engineering education follow:

| | |
|---|---|
| Instructional salaries | 51.5% |
| Administration salaries | 5.3% |
| Current expenses | 18.5% |
| Equipment | 4.2% |
| University expense charged to engineering | 10.2% |
| Maintenance grounds, buildings | 10.3% |

In 9 endowed polytechnic institutes the cost per student per year (including interest on investment) ranged in 1924–25 from $384 to $888 with an average of $750. The investment per student ranged from $4,000 to $14,250 with an average of $10,750.

In different types of schools the annual cost per student was as follows: endowed universities $742, endowed polytechnic institutes $750, state universities $474, schools of mines $738, land grant colleges $437.[344]

The cost per student is much greater in engineering education than in liberal arts.[345]

## V. Conclusions and Recommendations

With the assembled facts and opinions concerning engineering education the Board reaches the following conclusions in addition to those in the preceding sections.

*An Undergraduate Course* should equip wholesome and qualified youth with a basic acquaintance with science, familiarity with engineering methods, and an appreciation of social relations.[84] These should be coördinated in time and in content and brought to a focus during the last year upon the students major subject.[140]

Three types of activity common to all engineering, for which the undergraduate program should provide a basis, are:[84]

1. The control and utilization of the forces, materials and energy of nature;
2. The organization of human effort for these purposes; and
3. The estimation of costs and appraisal of values, both economic and social, involved in these activities.

An educational process appropriate to these purposes cannot be narrowly technical.

*Engineering Education should be a unified process* in which scientific technological and humanistic studies form an orderly whole; a self contained branch of higher education under unity of supervision.[122] This is in contrast to a divided program having a pre-engineering curriculum under separate administration and a subsequent purely technical curriculum—corresponding to practices in law, medicine and dentistry.[112, 105]

Engineering education is good general education; it is characterized by a coherent and integral program, unifying an otherwise loose group of studies by professional orientation which becomes increasingly significant in the upper years and dominates the post-graduate period.[85, 140]

*Four years,* as at present, is the recommended norm for an under-graduate course leading to the bachelor degree. Following present high school graduation this implies a median age of 23 at graduation.[85, 138] Students should be at liberty to extend the period to five years to include additional subjects or to overcome handicaps in preparation.[139]

*Continuation Education.*—College training should be the foundation for the continued development of the graduate either as a professional engineer, or in other fields, by either of two principal methods.[139, 1102]

By resident graduate study preliminary to his future work, technical and professional or administrative or other.

By entrance into practice where experience may be accompanied by continued post scholastic study.

### *Development from Within*

The Board proclaims principles; it does not prescribe rules. Engineering education cannot be static; it has been and must continue to be an evolution.

Engineering education can cope with enlarging responsibility to society and increasing exactions of professional practice by enhancing its own distinctive qualities rather than adding unrelated elements from without. Emphasis on humanistic subjects for enriching the conception of engineering and its place in the social economy, a more connected and better grounding in engineering principles; and greater capacity for self directed work may all be gained at the expense of unrelated studies and detailed training in technique. The latter should find place in post graduate and post scholastic courses.[140, 1048]

*For Better Engineering Education* we must look to better balanced curricula, better selection of students, better teachers, better methods, better subject matter and better advanced training rather than changes in educational organization.[141]

*Developing Teachers.*—For developing teaching personnel each school should have a policy and a definite program covering selection, guidance, engineering experience and teaching methods. Means may include summer schools for engineering teachers, conferences with engineers and with industry.[106] Engineering schools should provide adequate salaries, and encourage participation of teachers in engineering practice.[107] Teaching loads should not prevent personal development and contributions to engineering progress.[108, 1090]

### *Other Recommendations*

The Board states its views on various matters and offers suggestions. Some of these follow.

*The credit hours* in four years should not exceed 144. Simultaneously carried subjects should not exceed 6.[86]

*The Curriculum* should be common for all engineering freshmen but for the last year may be widely differentiated; in intermediate years adjusted to local conditions.[86] Options in later years are desirable.

*Concrete projects, lectures and conferences* should stimulate interest, orient to engineering activities and serve as a try-out of aptitude.[89]

*Social and Economic* studies should reveal the broad inter-play of social forces and also the specific economic problems and social situations in the realm of engineering.[90, 1048, 1156]

How to place proper emphasis on engineering economy is an open field for experiment by the engineering colleges. General economics should be taught with consideration to the engineering view point.[91]

*Specially gifted students* should have special programs. Particular programs depend upon sizes of classes and available facilities.[102]

## VI. Need for a National System of Technical Education

The engineering college has been reviewed as to its own content and in its relation to preparation of students in earlier years and to the subsequent activities of graduates. What is its place in the American system of technical education? How do our methods compare with those abroad?

We have no national system. Our facilities are concentrated in the engineering college, while provision for other fields is neglected. Technical education is a product of industrial, social and political life and ideals, and in turn is a factor in national development. This is clarified by experience in other countries which indicates that either *laissez faire* or a bureaucratic policy may entail dire national consequences.[142]

*France* showed remarkable early fertility in technical education and held undisputed leadership up to 1850. Then followed forty years of arrested development; the state held a monopoly of higher education under the bureaucratic system but took no effective initiative; local and private initiative finally took up the burden, but only after the late War did the state resume its responsibility for a balanced and adequate development. Meanwhile the early supremacy had been irretrievably lost with far-reaching effect on French industrial development.

*Great Britain*, on the contrary, lost fifty years of her early industrial lead over Germany and the United States by leaving all technical education to local and private initiative under an extreme *laissez faire* policy. Britain was equally slow to perceive that a specially selected and trained personnel was needed to apply science to industry effectively. Nearly a century of her effort was concentrated on the incidental education of workingmen, while technical education in the universities was nearly stifled by neglect. It has taken nearly forty years of intensive effort to redress the balance.

*Germany.*—Technical education in Germany, after being thrown out of the older universities by conservative educators, was taken up and fostered by far-seeing statesmen bent on transforming a group of backward agricultural states into a powerful industrial empire. Nowhere else have technical education and research so largely shaped national destiny. After 1860 it was increasingly clear that while the states and the industries were supplying the motive power of technical education, it was the engineering profession working with educational leaders which was guiding the movement out of its early confusion into a well-ordered scheme.

In the *United States* the pioneer efforts of Gardiner and van Rensselaer, and of their proteges Hale and Eaton, "to promote the

application of science to the common purposes of life" quickly solidified into one special form, that of a professional discipline for engineers. This in turn, was quickly assimilated into the collegiate branch of the educational system which at that time was just taking on an orderly form. Engineering education was already firmly established when the engineering profession became an organized body. In consequence of this early fixation, technical education has had a vigorous development in only one compartment of our educational system. It has developed independently, without guidance by the profession or effective bonds with industry. Its aims have been largely individualistic. The early definiteness of aim has been impaired by the effort to make a single type of school cover the entire range of educational needs. Meanwhile inadequate provision has been made for large sections of our youth in need of technical preparation and industry has been given an unbalanced recruitment.[142, 143]

*Our Engineering Colleges* are attempting too broad a field, handicapping their true function. A conspicuous need is non-collegiate technical institutes (considered in section IX). Engineering schools require external re-adjustment; they should be relieved of other levels of training.[144] Within their own field engineering schools should not conform to a single pattern, but may develop distinct spheres of work. Students may then select schools and schools may select students. Distinct types of schools may prepare for the higher intellectual and the higher practical functions of industry and of engineering.[146] Some institutions should concentrate on the higher intellectual aspects of engineering both undergraduate and graduate.[146]

*A National Agency* to consider the whole field of technical education and the external relations of engineering colleges cannot be expected in our government or in industry or in the engineering profession or among educators; it is too big a task for this Society; we must look to some joint representative agency, professional, industrial, educational.[144] That is the solution in America for control which is exercised abroad by public authority and the organized professions as technical education is there considered a part of the national economic system. In America the aim is individualistic—the development of the student. We do not aim to fit men into predetermined molds. National aims and ideals differ. We cannot copy, we must initiate our own national system.[1001]

## VII. Our Engineering Schools in Perspective

The "Comparative Study of Engineering Education in the United States and in Europe" [750] by Director Wickenden contains much information on the development and existing condition in

the various fields of technical education in the leading industrial nations. Its significance is in new view points on our own situations. National systems have been considered in the preceding section.[1000]

*Quantity Production and Intellectual Standards.*—Quantity production of graduates for ordinary needs of industry acts against highly selective schools of high scientific standards. The public rates schools by excellence of plant and size of enrollments. Preparation for the practical direction of industry and preparation for its intellectual leadership are not separated here as they are abroad; as consequences the production side of industry is underrecruited, and on the other hand America has been a large importer of analytical, design and research ability. American engineering is far from being self-sufficient on its higher intellectual levels.[1002]

*Preparatory Education* abroad has teachers with a standard of intellectual and cultural qualifications quite equal to the average in our higher institutions. Abroad, secondary education is a selective process with great continuity of subject matter preparing for definite intellectual pursuits, but here the aim is not primarily intellectual, rather it is social, aiming to fit young people into spheres of life different from that of their fathers. While we may not reach European levels we ought at least to enable capable young men to reach their present high school graduation levels at 17 or 18 instead of 19 years of age. Improved preparation is an effective way to improve engineering education.[1003]

*Curriculum.*—The American formal curriculum stands well in comparison, but we have limitations in secondary education and in thoroughness of mastery and coördination of basic sciences. Our sequence of subjects is good, although mechanics often comes too late. We are deficient in the mastery of the few key principles. We lag in the construction side of engineering. This is being remedied in a measure by the courses given by the large electrical industries, pointing a way which others should adopt.[1004]

*Specialization.*—Our differentiation in curricula along the major professional lines is supported by foreign experience. Although American colleges have a reputation for innumerable curricula and degrees, yet about five sixths of our students are enrolled in the five principal branches. Germany has commendable group options in the upper years of a few major "faculties."[1005]

*Teaching Processes.*—Textbook daily assignment, recitation, written quiz, piece-meal grading; also our pedagogic devices to compensate for defective mastery of the processes of learning demonstrate the juvenility of our higher education. Deficiencies in preparation, indefiniteness of aims, lack of social and economic

urges to achievement, the lack of intellectual traditions in society and of standards of scientific competency in the technical professions have compelled our engineering colleges to resort to a driving process. The American student has less freedom and more routine; he is not an independent spirit striving for a distant goal; he is a harried quantity producer with recurring daily and weekly tasks. We may accomplish more with the average student, but we sacrifice the superior student of originality and imagination. The root of the problem is in the teacher, often overloaded and ill prepared to teach his subjects and with little conception of better ways. We have not studied how to handle large groups. Our students expect to be taught. Our leadership is quantitative. Electrical students at Stockholm, Delft, Berlin and Zurich were observed to have less equipment but presented laboratory reports showing critical analysis and little of manipulation, observation, descriptive writing and compiling.[1006]

*Training in Management.*—It has been easier to introduce the economic sciences into our technical education than in the compartmental systems abroad. France has been successful due to rigorous selection, high intellectual formation, professional teaching by eminent practitioners, industrial *stages,* officers training with the army and the confidences and solidarity bred of being a *Polytechnicien.* American curricula in industrial engineering and management are attracting attention abroad. Qualified teachers with responsible experience are hard to find abroad as well as here. The revamped economist, psychologist or statistician is no nearer the engineering ideal there than here. Management is still far from a mature and orderly science. Higher education for business is not going any too well abroad and is not the rival of technical education as it is in the United States. German technical universities conduct research on selection for industrial vocations and on laws of efficiency of human work. Research first, teaching afterwards.[1007]

*In Technical Research* (1927) our institutions are in advance of France, behind Central Europe and only on a par with Great Britain although our university organization is on a vastly greater scale. Until recently our colleges have regarded research as merely an incident. Few men of high research ability are in the schools; they are in industrial research. Research personnel cannot be improvised; that of Germany is the product of a century of cultivation and selection. We have had a scattered policy, bringing a large area under cultivation rather than the intensive cultivation of a few plots. A strong spirit of inquiry and creative effort in our colleges is more important than juggling with curricula. Good students educate themselves if environment permits. Pure scien-

tific research is an indispensable adjunct but not a substitute for technical research.[1008]

*Status of Engineering Teachers.*—The prestige of the engineering professor is higher in each of the ten European countries visited than in the United States. In comparison it appears that many of our engineering teachers are industriously attempting a task for which they are inadequately prepared, either by scientific training, professional experience or broad personal culture, and that the technical professions and industries of America do not keep teachers of highest fertility at the source of their recruitment. Germany practices what we do not yet clearly envisage. The present rise of scientific standards was not anticipated in the training of many teachers now in middle life who will remain in front line positions for many years to come. We should concentrate on a dozen best equipped institutions in raising the levels of graduate work; send selected men abroad; send men from industry to graduate schools, and keep our most promising men free from deadly routine.

Although American teachers may lack in scientific attainment they excel in devotion to the improvement of their processes and the individual welfare of their students.[1010]

*Student Life.*—The multifarious activities of student life give worthwhile opportunity for self-discovery and personal experiment which are often the basis of future careers. The problem is one of proportion. Normal participation in general activities should not be strangled by an academic load of routine. English sport is far more wholesome than our high-powered competitive athletics. Self-support may divert too much of the student's energy. It is not in favor abroad. We should consider deferred payments or coöperative methods rather than to depend too much on casual earning power.

*Integration of Academic and Practical Training.*—In theory our technical profession upholds that practical training is indispensable to the engineer; in practice it is left to the individual to do the best he can. Only a few concerns in the electrical and chemical industries train broadly. Other employers usually train for their specific needs rather than as part of a broad professional development.

British and Germans insist that practical training shall have form and substance.

Where the coöperative plan is impracticable other means should be found for systematic practical training. The schools, professional bodies and industries should come to clear agreement on aims sought and specifications to be met. Until the colleges know what training employers will furnish they cannot intelligently adjust their own courses.[1012]

*The More Intensive Form of Higher Education.*—Our concentrated effort on degree-granting colleges is in sharp contrast to European methods which provide a comprehensive system directly adapted to the needs of industry. They give intensive training to the less book-minded who lend themselves better to more direct practical and inductive methods of learning. This subject is elaborated in Section IX, Technical Institutes.

*Conclusion.*—We are training American youth for American life. Our teachers must guide as well as instruct. Our students must experiment with life as well as with mechanism. Our colleges must supply incentives from within which abroad are supplied by economic pressure from without. Part of our technical education must be lifted to higher scientific levels.

The crux of our problem is to unite a higher concern for individual development with both a higher intellectual standard and a higher practical standard of technical preparation. These ends are achieved abroad through selective processes which reach to the very foundation of the social structure. No single type of school nor compromise type of program will solve our problem. We need more clearly visualized aims and programs to develop a willingness to accept different but equally worthy functions in the social order. The situation is a joint responsibility of educators, the technical professions and industry. It is a test of American capacity for self-government through group coöperation.[1014]

## VIII. Summer Schools for Engineering Teachers

Of all the many ways in which it was found that engineering education might be made better, the outstanding one was better teachers. Whatever might be done in the future to select and develop teachers there was the immediate present problem, How can the quality of present teachers be improved? In a previous section it is recorded that many faculties considered training in the methods of teaching as desirable, but questioned its practicability. Happily a plan of teacher development was evolved and put into effect on a scale large enough to produce useful results and also to indicate the desirability of continuance.[1117]

The Summer School project brought together teachers in a particular subject for a three-weeks' session in which they might qualify as better teachers. Programs of the sessions included lectures, model teaching exercises, laboratory and lecture room demonstrations, seminars, and work carried out by committees of members of the groups. Methods of teaching were stressed in all parts of the programs; subject matter being considered chiefly in its relation to method. At each session advanced phases of the subject under consideration were presented with the purpose of stimulating interest and promoting further study.

In all there were 12 sessions, two during the first summer devoted to mechanics and others later covering subjects of electrical engineering, mechanical engineering, civil engineering, chemical engineering, mining and metallurgical engineering, engineering drawing, physics, mathematics, economics and English. The total enrollment was 721, an average of 60 per session. The members of the staff totaled 376, an average of 32 per session. The average number of institutions represented at each session was 41. Many of the presentations by staff members were written papers. Selections from these of more general interest were published in the Society publications or in those of the Civil and Mechanical Societies and reprinted in bulletin form. Assembled these would make volumes of some 1,700 pages, the cream of the presentation of experts in many fields. Papers dealing with the historical, technical and pedagogic phases of the various divisions of engineering teaching.

Some of the groups have maintained a continuing organization, holding conferences in connection with annual conventions of the Society.

The Summer School was the prototype of the notable conferences in connection with annual convention in 1934. A score of groups primarily of younger men held conferences on many phases of engineering education on the two and a half days preceding the opening of the convention. About as many participated in these intensive and animated presentations and discussions as were enrolled in all the sessions of the Summer School.

The Editor of the American Society of Mechanical Engineers, a former teacher and a member of the Council of The Society for the Promotion of Engineering Education, attended the Summer School for Mechanical Engineering. He reports (condensed):

To evaluate the results one must give substance to many intangibles. A golden opportunity for the young instructor, subjects were presented in a new light, old problems were given new significance, and inspired enthusiasm, sectionalism was dissipated; teaching problems are fundamentally the same. Fortunate the college whose faculty have the more mature outlook which the school affords; notwithstanding this more than half of those attending received no expense funds from their schools.

Engineering societies have a stake—their future is determined by the quality of graduates the schools produce; hence they are concerned with the sort of teachers who train engineers. For three weeks deans, professors and instructors lived together, ate together, sat together in class rooms, 90 of them came from 60 institutions in 36 states and two Canadian Provinces.

The staff selected from colleges and industries contributed a rich program. The program at times simultaneously dealt with heat power, machine design and production; these were handled by experts interested in the teaching of these subjects.

Some impressions: A reassuring conviction that teachers of engineering are on the right track. In an age of sudden changes and new environment methods of education change; engineering teachers have preserved a conservative balance with progressive vision. They are unique in boldly questioning their aims, ideals and methods with the hope of improving themselves, their schools and their product. They have been unique among teachers in the thoroughness of their studies and in definite formulation of their essential ideas. Colleges of liberal arts with varied programs have not worked out definite plans as their objectives lack the definiteness which gives form to the engineering curriculum and the educational needs of the graduate engineer.

## IX. A Study of Technical Institutes (1928–29)

### *Principal Findings and Conclusions* *

*Occasion for the Study.*—Our several branches of technical education have grown up independently. The field has been open to free enterprise, and it has been nobody's business to explore the whole situation and plan comprehensively. Certain dominant types have emerged, but we have created nothing which resembles the carefully conceived and articulated national systems of technical education which exists in Europe. We have had the benefit of much unhampered pioneering, but have permitted broad gaps to develop.

This study deals with one of these gaps. The engineering college is one of our strongly defined types of institutions, and trade and craft schools are acquiring a more typical character and standing. The type of institution known in Great Britain as the "local technical institution," and the "technical middle school" of Central Europe have only a few and scattered counterparts in America.

*Characteristics of the Technical Institute.*—A school of post-secondary type, but distinct in character from a college, to train for callings and functions between the skilled crafts and the highly scientific professions. Many graduates advance to a professional status principally those who have found their bearings and desire intensive preparation for chosen lines. Training is both for technical pursuits, planning and control, and for supervisory positions, operation and maintenance. The engineering college emphasizes the former, the technical institute the latter group. Intensive in purpose courses are shorter than those of the colleges. Without academic standardization admission and graduation requirements are less formal and stress capacity and experience more than credit units. Teaching is relatively direct with emphasis on doing as

* The Full Report is in Volume II, Part 2.

distinct from book study. Teachers, while possessing adequate scholarly preparation, are chosen primarily on the basis of practical experience, personal sagacity, and ability to teach through programs of orderly experience. Instruction follows the actual usage of industry.

*Summary of Principal Findings and Conclusions.*—With the rapid shift toward higher standardization and automatic processes, the total force requirements in American industry tend to diminish, but there is a striking rise in the proportion of staff experts and of highly trained technicians and supervisors. Industry must therefore look increasingly to technical schools rather than to its rank and file for its technical and supervisory personnel.

The situation in industry warrants a great expansion of technical education above the present level of the secondary schools. There should be a greater diversity of technical education to serve a wider variety of individual and industrial needs. To maintain but one type of school (the engineering college), and to ask it to meet all purposes is to invite blurring of aims and compromise of standards. The need is for schools having more definite purposes and more clearly visualized aims.

Engineering colleges, graduating about 9,000 men each year, leave many of the needs of industry unprovided for. Engineer and sales staffs are fairly well recruited; production, operating and maintenance staffs most inadequately. Manufacturing industries estimate their normal requirements of four-year engineering graduates at from 2.2 to 3.0 per cent of their total forces. This potential demand is perhaps one third supplied. The same industries estimate the desirable quota of employees having approximately two years of training above the secondary level at from 6.0 to 8.3 per cent of their total forces. At present this potential demand is not more than one fiftieth supplied and an output of from 25,000 to 30,000 graduates a year from technical institutes could be absorbed to great advantage.

Graduates of technical institutes have shown adaptability to the requirements of industry in the following order: supervision in operating departments; plant operation and maintenance; getting on with workmen; technical services (drafting, designing, testing, inspection, etc.); team work with associates; coöperation with executives; construction and erection in the field; accepting plant hours and conditions; technical sales work. The largest groups are supervisors, engineering personnel and proprietors of business. These graduates are somewhat more stable in their early employment than engineering college graduates. The median earnings of the two groups, for equal age and experience show only a moderate margin in favor of the college men. Wherever the product of the

technical institutes is known, the demand greatly exceeds the supply.

The technical institutes cater effectively to young men who have industrial experience and orientation, to men who have a career definitely planned, to men who have passed out of a state of book-mindedness, to men whose natural learning processes center in actual doing rather than formal study and to men who for financial or other reasons cannot devote four years to preparation.

Enrollments in day technical schools, both full-time and part-time, can be greatly increased. The urge toward technical pursuits normally asserts itself between the ages of 16 and 19. Technical education needs to be made widely available locally, a technical institute might thrive in most cities of 50,000 or more.

Technical institutes should have their own distinctive field and character. Attempts to give the more intensive and practical forms of post-secondary technical education in auxiliary departments of standard engineering colleges have largely failed, through becoming salvage courses for failures in the longer courses. Wherever its distinctive aims are not clearly visualized and tenaciously pursued, the technical institute tends to drift into the college field, often to the neglect of the very groups it was created to serve. The mixed type of technical institution has succeeded well only in Great Britain, where a powerful tradition and the strong hand of the central authorities unite to keep the non-degree courses in a dominant position.

There is no basis in experience for expecting the junior college of a mixed character to do the work of a technical institute successfully. The technical institute needs a director and staff who are in intimate touch with industry and especially proficient in blending scientific and practical instruction rather than leadership of the "educationist" type.

The day technical institute with an evening department is the objective. It is difficult to maintain an efficient staff for evening work, unless the school is an auxiliary to a day school or to a large industrial establishment.

The coöperative plan, based on alternating periods of school work and industrial employment, seems particularly well adapted to the aims and the levels of age and work of the technical institutes. The coöperative plan does not obviate in any large degree the need for extensive scientific and technical equipment; in fact the demands on equipment in a technical institute are fully as intensive, if somewhat less varied, as in the engineering college.

Much of the success of the European institutes is due to their close adaptation to regionally specialized industries. Monotechnic schools in such fields as textile manufacturing and bituminous coal mining are especially dependent on environment for success.

The actual needs and the potential demands are beyond the resources of voluntary and private agencies, although the latter have important contributions to make to the enterprise as a whole. The needs of the country could scarcely be met by less than 250 institutes, and seem to call for the creation of a great chain of community institutions having an organic place in city and state educational systems, yet free to achieve their own distinctive character.

The independent, endowed technical institute resembels the endowed college or university. In American experience private initiative has been quicker to recognize neglected areas of education and to occupy them than public authorities. After successful efforts have gained some prominence, the public steps in and meets the larger needs. The independent schools are then able to capitalize their freedom for experimentation with curricula, teaching methods and selective standards of admission. Welfare organizations have entered this field with the aim of serving men not provided for by other agencies at the level of their actual needs. As a rule these organizations have been under the necessity of making their educational activities pay their way in full. The temptation to "window dressing" has been strong and the limited resources, personnel and equipment have left room for doubt as to the quality and permanence of their work, if once the public awakens to its responsibility.

Cities of less than 50,000 population, would find it impracticable in most cases to maintain municipal technical institutes. If this gap is to be filled it must be done largely by the states.

The largest field to be served by the technical institutes appears to be that of training men in the technology of particular industries rather than that of generalized engineering courses of broad aims. Schools for specific industries are greatly needed and no question of depressing professional standards can possibly be raised. Schools for the textile industry, the foundry, machine production, instrument makers, building construction, printing and engraving, horology, coal mining, and the leather industries are types widely established abroad and in great need for multiplication in America. These industries could use great numbers who have had two years or more of training adapted to their specific needs.

A lack of solidarity among the existing technical institutes has held back the development of similar schools over the country at large. Each institution has grown up around some local situation or some individual's vision, but with little sense of aims in common with other schools. Their heads have wisely sought to preserve this individuality. The result has been an emphasis on points of dissimilarity, amounting to a spirit of mutual aloofness. Thus

separated, they have been unable to create a recognized status of their own. They were too often known as non-this or non-that to impress themselves on the consciousness of the country, much less its imagination. Their faculties suffer from a sense of professional isolation. There was no forum for their common problems and no organization for a united initiative.

Technical institutes have been handicapped by the fact that their graduates received no educational credentials which are nationally recognized. The temptation has been strong to become colleges and award degrees. British educational authorities and professional societies have met a similar problem most effectually through the establishment of National Certificates, National Diplomas, and Certificates in Technology awarded by central bodies.

*Training in the Technology of Specific Industries.*—Courses in the technology of specific industries involve a higher order of specialization than an engineering course, yet not necessarily a narrow training. Printing, iron-founding, coal-mining, photo-engraving, tanning, papermaking, cotton-spinning, watch-making, die-casting, framed construction have each an underpinning of scientific knowledge and a content of rational practices. Each draws selectively on many sciences. One need not know all of chemistry to be an expert in paper making or all of physics to master the art of cotton spinning or weaving.

*Training for Specific Technical Functions.*—This type represents a high order of specialization. An example is the work of the quantity surveyor, who takes off from building plans complete schedules of the quantities of materials, areas, volumes, numbers of unit items, etc., from which bidders may estimate their costs. One must have intimate knowledge not only of plans and conventions, but also of specific details of construction not represented on the plans. On the other hand, a limited knowledge of design calculations for strength and resistance, and the like, will suffice. In educational courses of this type it is entirely practicable to proceed from a detailed job analysis and one may safely trim the program to strict essentials. Most of these specific functional jobs have outlets to posts of responsibility. This field of education belongs by rights to the technical institute.

Much of the demand on the engineering colleges could be filled by technical institute graduates. Thus relieved, the colleges could emphasize more truly professional aims and standards. From the viewpoint of industry, a thoroughly trained technician or operating supervisor ought to be more acceptable than a half-baked or ill-adjusted engineer.

*Data re Technical Institutes*

*Requirements of Industry.*—Fifty-five manufacturing companies in New Jersey report their needs for technical men from technical institutes and from engineering colleges as follows:

| Branch of Engineering | Technical Institutes | Engineering Colleges |
|---|---|---|
| Mechanical | 817 | 316 |
| Electrical | 116 | 111 |
| Civil Engineering | 6 | 18 |
| Chemical | 345 | 146 |
| Mining | 6 | 4 |
| Miscellaneous | 12 | 0 |
| Total | 1,302 | 595 |
| Ratio | 2.8 | 1 |

Another group of 21 New Jersey industries reported a ratio of 2.7 : 1.

Public Utilities of New Jersey (not including communication) reported a ratio of 2.7 : 1.

Employment managers of 12 large companies in California in a classification of 75 types of technical positions found a ratio of 2.6 : 1.

These closely agreeing results from four independent sources are impressive.

*Estimated Positions Available* for graduates of technical institutes (1928) is 40,000 to 50,000 annually. This is based on census reports of the number employed and upon the ratio recommended for technical institute graduates to total employees by companies using such graduates.

*Aims Suggested* for technical institutes by 15 concerns who used graduates were in order of importance for qualifying men (*a*) for supervisory positions in operating departments, (*b*) for technical service, *e.g.*, drafting, designing, testing, (*c*) for commercial positions relating to sale of technical products.

*Records of Graduates.* A high percentage of graduates report general satisfaction with their courses as a preparation for their careers. Over 80% indicated need or desire for additional study although less than half of these had enrolled in additional courses.

The lack of a degree was a handicap to only about a quarter of the graduates in securing employment or in securing advancement, or in recognition by professional or business organizations.

Five sixths of the graduates were employed in fields the same or closely allied to their school courses.

Outstanding traits were adaptability to supervisory, operating and technical services, ability to get on with workmen and to do team work and to coöperate with executives.

Earning power of a group of 1,000 two-year technical institute graduates is within about 5% of the earnings of a large group of four-year college graduates. The earnings of 200 one-year graduates is 15% to 20% lower for the first 10 years after graduation and then advances very slowly.

*Students.*—The fathers of students are proprietors and employees in business and industry, 70%; farmers, 12%; professional and brain workers, 18%.

High school graduates range from approximately 50% to 90% in 13 institutions.

The median age of students in eight day institutes ranges from 20 to nearly 22 years. In five evening institutes from 20 to 24 years. More than half of the day institutes have students over 30 years of age and all but one of the five evening institutes have students over 35 years of age.

The day institutes have students with prior full time industrial employment over 75% and evening schools over 85%. Nearly half of the students earn three quarters or more of their expenses, some prior to entrance, some during vacations and some during school time.

*Qualifications of Teachers.*—In 10 representative institutions 70% of the teachers hold college degrees. Of 239 reporting 39 hold the master's degree and 45 professional degrees in engineering. A very large proportion of the teachers have a number of years experience both in industry and in teaching. Nearly a third of the teachers are below 30 years of age and about a third are over 40.

*European Institutions.*—In European countries the technical institutes are government schools. In France there are national schools of industrial arts; in Great Britain there are under joint support local and governmental more than 200 technical institutions; in Germany the higher industrial schools are under state and municipal auspices; in Switzerland the *technicums* are maintained by the cantons. The established character and the recognition of these schools as a part of the national economic system is in marked contrast to their position in America.

## X. Summary of the Results—the Intangibles

The findings of the investigation and the conclusions appear in the preceding sections of this summary. The initial purpose to study the objects of engineering education and the suitability of existing curricula resulted in a notable collection of facts and opinions regarding the many phases of engineering education. It was found that objectives and practices called for no revolutionary treatment and that improvement can best come from readjustments, and extensions and from betterments of quality.[1090]

Our American youth can best be served by an engineering college which offers a balanced ration of the scientific, the technological and the humanistic. This is a type of general education of scientific background preparing for many activities in modern life. It should be so shaped as to prepare for entrance to the engineering profession, either through graduate study or a combination of practice and post scholastic study, as preliminary to either the more technical or the more administrative field.[1056]

Betterments are proposed, particularly in the quality of entering students and of teachers and in facilities for college work by the highest type of students.

Technical education is surveyed on a national basis and it is found that the engineering college is attempting to cover too large a field; part of what it is attempting could be much better done by a different type of school with briefer and more intensive training—The Technical Institute. A study of engineering education abroad, which was included in the original program of the Investigation throws much light on our American methods.

The Summer Schools for engineering teachers demonstrated on a large scale the potency of extending opportunities to faculty members for self-development as teachers. This practical plan for the betterment of engineering education was based on the findings of the Board that what is most needed is better teachers.

It remains to point out other influences and results, often intangible as they cannot be measured quantitatively; their significance must be a matter of opinion; others may assign different values than those here implied.

*Engineering Education as a Whole.*—One's idea of engineering education is often based on personal experience as a student in a particular institution years ago. Even teachers sometimes are familiar with only one or two institutions. These reports present a comprehensive view—Engineering schools grown in 60 years from a half dozen to a dozen dozen contributing the men who did their bit in changing the ways of life and in building a Century of Progress.

Many independent no-two-alike schools with common purpose, loosely coupled in a Society for promoting their own quality, attaining closer "Coördination" by common endeavor to investigate and to solve their problems, an un-incorporated national institution.

What is the typical school and teacher, student and graduate, just how does the educational machine function, what is it accomplishing?

In the report are tables and charts, descriptions and summaries treating engineering education in the large, telling the story by facts gathered from un-numbered sources.

*The Complexity of Engineering Education.*—One is apt to think of engineering education as something simple and definite, but the successive sections of this Report reveal its inherent complexities and its external relations, all brought to focus on the few years in which the high school graduate prepares for his life work. The freshman himself—heredity, environment, education and ambitions; the curriculum—a resultant of traditions and local environment, a meeting ground for the humanistic, the scientific and the technological departments of instruction, the resultant of conflicting objectives and ideals which forms the actual program of contact between students and instructors; instructors—their ability, knowledge, personality, attitude, and skill as leaders; college life with its opportunities and temptations; the after-graduation period with its continuation of development and its hit-or-miss introduction into practical life; the contribution of the graduate to professional life, to industry, to public affairs and citizenship; the significance of scientific and technically trained men in industrial and social affairs and on the national economic system as revealed in the studies of different countries—all these are typical elements which are brought to focus in engineering education.

*Our Technical Education is Unbalanced.*—To the writer the outstanding surprise of the investigation was the fact that industry needs only one college man to nearly three men trained in another way—in a type of school which did not have even an accepted name, for which we coined the term Technical Institutes. Obsession for degrees and concentration on collegiate forms of education have unbalanced our system of technical education. The engineering colleges have been attempting work outside their own sphere. They can do much by internal improvements, but they need also new environment, better preparation of entering students, better continuation training for their graduates, more schools of different type in parallel to relieve the colleges of a misfit burden and to do well what the colleges are now doing poorly.

A recruiting agent recently asked "Who are your best men? In the past we have taken many and the merely good men have fitted into routine jobs, but we find the firsts from high schools and night schools go up faster than the seconds from the colleges."

Industry is now practicing the selective admission which is advocated for the colleges.[1077]

*Stimulation of Interest in Education and Teaching.*—An initial principle and a final conclusion is that betterment should come from within. The method of the Investigation has promoted that development. The Society accepted the challenge that it undertake its own problems. There was formal participation by seven or eight hundred faculty members in committees which collected

data of their own students, teachers and graduates. Knowledge of their own conditions and problems prepared them for interest in assembled data affording comparisons. The enormous amount of arduous work done voluntarily in the assembling of data and the preparation of reports by faculty members is strong testimony to the interest of college teachers in their work.[1042]

Appreciation that there is a problem and its formulation are first steps to its solution. A leading dean remarked that never before had his faculty really become animated in discussing their educational problems. An outside observer whose contact with schools gives a valid basis for his opinion says the outstanding result of the Investigation is improvement in teaching, brought about through direct training and the comparisons, direct and indirect, which have spurred on to new methods.

*A Basis on which to Build.*—Engineering teachers and administrators have remarked that these reports give a basis of fact on which to plan. What they only thought was so, now they know is so.

Papers presented to the Society proposing educational advances take the recommendations of the Board as their starting point. Our reports are used as guides in plans for industrial educational projects. The reports have supplied arguments for strengthening curricula.

*A New Solidarity.* Working together creates comradeship. Near sighted deans, teachers in ruts, isolated institutions have new perspective, new fellow feeling and understanding. The Society is not an organization devoted to the publication of idealistic papers but it is a coöperative institution. This has been fostered by effort in a common cause and by reports and data which have made institutions which were strangers familiar with one another. Our hundred and more institutions with their thousands of faculty members have been given a new union and new solidarity. This has been made concrete by the practical tangible character of the Investigation.

There is a new unity between related departments. The Summer Schools for Teachers of Physics and Mathematics and English and Economics have led to mutual understanding and purpose. The departments have not been treated with aloofness but as important contributors to engineering education, they have new understanding of engineering ideals and purposes.

All this is in realization of the ideal which is incorporated in the title of the Board, "Coördination."

*The Engineering Societies.*—The Board has sought to bring the engineering societies in closer relationship to the schools. Its headquarters were located in the Engineering Societies Building. The

societies have long maintained student branches. At the beginning of the investigation they appointed counselors and later contributed opinions by leading members, they contributed funds for the Summer School and participated in them. They have developed an increasing interest in education. They have recently joined with our Educational Society in the Engineers Council for Professional Development, looking to a comprehensive scheme for the development of the professional engineer. Incidently it may be mentioned that the program of the Council follows closely a schedule presented by Director Wickenden in a paper entitled, "What the National Societies Can Do for Engineering Education," presented before the American Society of Mechanical Engineers in 1927 and that a considerable number of the Council are former members of the Board and Staff.

These relationships may develop into that representative agency for engineering education which the Board has advocated. All this is further realization of "Coördination" which has been a dominating ideal.

*Orientation of Engineering.*—The survey clarifies many relations within the individual schools and many inter-relations between schools; also between the educational institutions and industry, and the professional societies. A better appreciation of these relations tends to a unity by welding together the elements which enter into engineering. Contemplation of the whole gives new dignity to the profession looked upon from within or without. It gives a sense of sweep and unity in engineering education as an ascendant, possibly a dominant influence in our twentieth century civilization.

*A Perspective View of the Investigation.*—Professor Hammond, actively connected with our project through the stages of the investigation and the Summer Schools, concluded a recent letter with the following paragraph:

"The work of the Society, under the Board's direction—the two Investigations, the Summer Schools, the Administrative Conference, and all of the attendant activities—have constituted one of the major programs of study, investigation and movements for betterment in the entire field of higher education. I doubt whether any other more comprehensive, or more fruitful, endeavor has ever been undertaken and carried through in any division of education, not even excepting medicine. We have been so close to the woods that we are inclined to speak only of the trees, meaning number of publication, number of pages, details of all sorts, that we forget what a large undertaking we have been concerned with."

*Finale*

And now comes to a close the formal existence of the Board and of another chapter in the development of the Society for the Promotion of Engineering Education. Formed in 1893 to promote engineering education it has been a pioneer in self development. During more than half of its two score years it has conducted investigative projects. In 1907 it initiated a formal study of its field and its problems, in which external agencies predominated; then in 1923 it undertook a coöperative self-investigation which developed an expanding program whose results are here recorded. Thus is carried forward the ideal on which the Society is based.

The Board has proposed no leap into Eutopia. Engineering fashion it has first found the facts. If we know where we are and the way we have come we can better determine where to go from here.

This "Final Report" does not mean finality, but like a diploma it signifies for the Society a Commencement time of a larger life.

Of the results of the investigation, tangible and intangible, possibly the most potent may prove to be the inspiration and stimulation of younger teachers to careers which in future may "develop, broaden and enrich Engineering Education."

## BOOK REVIEWS

*The Design and Use of Instruments and Accurate Mechanism.* T. N. WHITEHEAD (Assistant Professor, Harvard School of Business Administration, Late Scientific Officer to the British Admiralty). The Macmillan Company, New York, 1934. 6 by 9 inches, 283 pages, illustrated, index.

This interesting book is a splendid discussion of instruments and their errors. It should be of distinct value to everybody who is interested in precision instruments or machines; to the user as well as to the designer.

Five chapters are devoted to an illuminating discussion of the theory of errors as applied to instrumental observations. The author points out the fact that the usual assumption of normal probability distribution of errors is often grossly at variance with the performance of a given instrument. He shows how totally unbiased disturbances may give rise to biased errors as a result of the design or construction of an instrument. He points out the principles of design with reference to the elimination of erratic errors and the reduction of systematic errors, and indicates methods whereby these results can be attained with the minimum dependence upon superior workmanship.

In discussing the design of instruments, the author uses for illustration several types of commercial measuring microscopes, and he builds upon these machines a discussion of principles of wide applicability. A hasty glance at the book may lead one to suppose that it is a treatise on the design of this particular device. Such a conclusion indicates a failure to distinguish the illustration from the theme.

The author has made a valuable contribution to the literature, which should be of service to engineers interested in investigation and testing, and to those who are concerned with the design of instruments and precision machinery. The text is pleasingly written and the argument is developed convincingly.

C. HAROLD BERRY.

*Design of Machine Elements.* VIRGIL MORING FAIRES. The Macmillan Co. First Edition. 468 pages. $4.00.

The author has written a moderately priced, well arranged, carefully selected and readable text on machine design. He has

eliminated much empirical data for which the average engineer has little use but has included it when necessary.

A brief discussion of the properties of materials and how they effect design is given in Chapter I. Chapter II gives a brief review of elementary stress analysis. This subject is further amplified in Chapter XI where combined stress is treated. These two chapters add much value to the book and should be of help to the student.

The chapter on bearings is up to date and reviews the more recent experimental developments that have influenced bearing design. A chapter on welding is included in the book. In this chapter the various types of welded joints are discussed, the method of determining stresses and the working stresses to be used are covered.

The book discusses fatigue failures and endurance limit but in the writer's opinion does not bring out the full importance of this subject. The book likewise fails to give data on stress concentration in fillets and does not discuss the effect of stress concentration on fatigue failures. Since the combination of stress concentration and fatigue causes the larger percentage of failures of shafting, axles, crankshafts, threaded joints subjected to pulsating loads, etc., these two factors deserve a more detailed treatment. The table on physical properties of metal should give some idea as to the value of the fatigue limit.

The inclusion of the kinematics of several of the machine elements is useful, especially for the non-mechanical students who do not ordinarily take a course in mechanism. The author works out many illustrative problems but does not include in the book, problems for the student to work.

EMORY KEMLER.

*Signals and Speech in Electrical Communication.* JOHN MILLS. 281 pages. Harcourt, Brace & Co., New York City.

Mr. Mills has written sixteen essays dealing with everything pertaining to speech and communication. They are so well written that most any one who is at all interested in these subjects can read them and get a better understanding of something that perhaps was terribly puzzling before.

Material which has been found uninteresting in other books has been skillfully written into these essays in a very entertaining manner, e.g., the title of No. 5, "Modulation, a Marriage of Currents" and No. 7, "The First War with Attenuation."

From the preface it seems that the author has tried to tell the "general reader" that which he needs to be told about the arts of electrical communication.

There are no illustrations or mathematical equations. This book should be read by all university students to increase their knowledge of and interest in the art of communication in which we all engage.

R. C. GORHAM.

*Differential and Integral Calculus.* CLYDE E. LOVE. Third Edition. New York, The Macmillan Company, 1934. xv + 383 pages. $2.75.

Professor Love's textbook needs no introduction to many teachers of mathematics, as the first two editions were very popular. No far reaching changes have been made in the new edition; the material has been rearranged slightly, an article has been added on the approximate solution of equations, and the entire text has been expanded somewhat. There are more illustrative examples and more problems; the number of problems is exceedingly large (more than 3500 in all), and answers are given for about half of them. The reviewer is glad to see that the text proper has been enlarged in places, although it is still far from being verbose. The student will find the numerous examples worked out very helpful. We are of the opinion that this is an exceptionally good book for use in the class room, but that it is too concise, and perhaps too difficult, for a home study course.

The needs of the engineering student have been kept in mind. Such topics as rectilinear and plane curvilinear motion, centroids, and moments of inertia are treated fully, and there is a long chapter on infinite series. There is enough material on differential equations to satisfy the demands of most engineers.

The number of formulas that the student is required to memorize is held to a minimum. The author states in the preface that the aim of the book is "to reward the student who strives for a real understanding, as distinguished from the one who works by rote." Diligent application on the part of the student should certainly bring him his reward.

WILLIAM I. MILLER.

*English for Engineers.* S. A. HARBARGER. 5″ × 7½″. 314 pp., 3d edition. New York, The McGraw-Hill Book Company. $2.00.

This is not just another book intended to help engineers and engineering students with their writing. "English for Engineers" is something more than a textbook. If a book can be practical, this of Miss Harbarger's is as practical as a can opener. Instead of giving pages to matters (all of dubious value) such as the use

of the library, proper placing of footnotes, and the size and color of paper to be used for student reports, Miss Harbarger tells clearly and concisely just how sales letters should be composed, of how dictation should be given, and of how letters of inquiry, instruction, and order can be made effective. And, although there are perhaps too few samples, there is good advice to the engineer on the proper composition of articles for engineering journals, of abstracts, of book reviews, and of the rest. There are at least two essays (I like to think of Miss Harbarger's book as a collection of essays rather than as textbooks), or chapters, which should be of special interest to all engineers and engineering students. Chapter VII, "The 'You' Attitude," is of merit because it pleads with the technical man to use the idiom, when he writes or speaks, which will be understood instead of the jargon and argot of the profession. Recall, Miss Harbarger says in substance, that your readers or listeners do not know all the trade cliches and technical terms you will carelessly or inadvertently use; write and speak clearly and simply. Chapter XXV, "English for Non-Technical Uses," is a worthy essay because it urges the engineer, graduate or student, to read beyond the confines of his profession. From rather romantic treatment of engineering materials in fiction or journalism, Miss Harbarger develops her reading list to include novels, poems, and dramas. "Of course," Miss Harbarger writes, "an interest in music, in art, in drama, will offer the same diversion and recreation as literature. Reading, however, seems to be the most universal."

If I were an engineer, I should resent a book title addressed to me as "English for Engineers." There is no doubt that the information contained in this book has real value and should be disseminated. And yet, why should the authors and compilers insist upon singling out the engineering profession for specific instruction? Every month, it seems, a book comes from the press, making a distinction between engineers and other users of the language. Perhaps the mechanical patterns of an engineer's report or thesis or paper for his journal is somewhat singular. Perhaps it is necessary to distinguish between the business letter of a mining engineer and that of a chewing gum drummer. But the substantial matters of gentlemen's communication are constant. Clarity, conciseness, correctness, ease of sentence flow, mastery of material, and unity of plan are the same (or should be) in a letter of congratulation or in a thesis on the strength of reinforced concrete. I repeat that the information in "English for Engineers" should be part of every technical student's equipment; but how much better would be a book that is "not a collection of theorems, nor a

rude detection of faults . . . but a gay and vigorous dissertation where delight is mingled with instruction. . . ."

JENNINGS HAMMER.

*Kinematics of Machines.* GEORGE L. GUILLET. John Wiley and Sons, Inc. 276 pages. Third Edition. $3.00.

The third edition of this well known text has not been radically changed. The author has added a number of problems to the chapters for class work and to the section on drafting room problems. The velocity image method of finding velocities has been included in the chapter on velocities in plane motion. This method was unfortunately not given in the first edition and was included in an appendix in the second edition. A second method of working epicyclic gear train problems has been introduced in this last edition and adds much to the value of the chapter.

This text will be found to be well suited for the purpose for which it is intended, namely, the use in an elementary course in mechanisms for sophomore or junior students.

EMORY KEMLER.

## NEW MEMBERS

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